BARRIERS TO HOUSEHOLD LEVEL SOLAR PV ADOPTION ACROSS AN INCOME AND STAKEHOLDER GRADIENT IN SOUTH AFRICA

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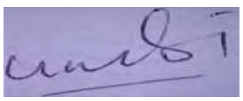
……………………..

SIGNATURE

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Abstract

The adoption of renewable energy technologies, particularly solar photovoltaic (PV) systems, is important in addressing global energy crises and promoting sustainable energy consumption. Solar PV systems offer the potential to provide affordable, clean energy, with the capacity to reduce carbon emissions and ease pressure on energy demand. However, in developing countries like South Africa, household adoption of solar PV remains low and limited, contributing a mere 5% to the national energy mix. This brings the question of why households are not adopting solar PV, given its environmental and sustainability benefits. Most studies on solar PV adoption at household level are in developed countries and tend to narrate views from high-income areas, leaving Africa and low-income areas understudied. This study aims to close that knowledge gap by exploring the barriers and drivers influencing the adoption of residential solar PV systems in South Africa, with a specific focus on income-level disparities. Specifically, the study examined (i) research progress and conceptual insights on barriers to solar PV adoption in South Africa, (ii) key barriers to solar PV adoption and how they vary between income groups, (iii) key primary motivational drivers and experiences of solar PV use among South African households, and (iv) key informants' views on the barriers to and policy options for solar PV energy adoption among households.

Firstly, results of this study show that financial, institutional, personal, and societal barriers contribute significantly to the slow uptake of solar PV technologies. A notable gap in the literature exists regarding the intersection of these barriers with income inequality, which is crucial for promoting a just energy transition. Secondly, results indicate that while high and low-income households face similar challenges, low-income households are disproportionately affected by limited financial resources, insufficient institutional support, and a lack of information regarding solar PV systems. Additionally, access to reliable energy was found to be a significant driver of solar PV adoption, with social influences, such as neighbourhood behaviour, playing a substantial role in household decision-making. Despite this, barriers such as inadequate knowledge of solar PV systems and security concerns regarding solar panels hinder wider adoption. Thirdly, the current solar PV adoption policy in South Africa is restrictive and inconsistent thus it requires improvements. To address these challenges, the study recommends tailored strategies, including flexible financing options such as solar PV leasing and power purchase agreements, designed to cater to different income groups. From a policy perspective, the study recommends the standardisation of renewable energy policies across different provinces to assume uniform rates of adoption and the liberalisation of energy market to allow private companies to generate and distribute renewable energy. The study concludes that low-income areas should be incentivised to adopt solar PV and collaborative efforts between government and the private sector are essential for promoting a favourable environment for solar PV adoption. Targeted policies, public education initiatives, and improved infrastructure are key to ensuring a just and inclusive transition to renewable energy, enabling households across all income levels to benefit from cleaner energy solutions.

Keywords: Solar PV, renewable energy, barriers, enablers, adoption.

CHAPTER 1: BARRIERS TO HOUSEHOLD LEVEL SOLAR PV ADOPTION ACROSS AN INCOME GRADIENT IN SOUTH AFRICA

1.1. Introduction

Renewable energy sources such as solar PV are central to many developing countries' transition to green and clean energy in response to climate change and energy insecurity threats (IEA, 2022; Abdelrazik et al., 2022). Households represent a major sector responsible for substantial energy consumption with negative repercussions on the environment, grid stability, and in turn, well-being and lifestyles (Dippenaar et al., 2021; Khine and Langkulsen, 2023). Despite the espoused transition to solar PV energy, evidence suggests that in developing countries, market penetration among households is low relative to developed countries, attributed to several financial, technical, educational, and policy constraints, among others (Dagnachew et al., 2020; IEA, 2022; Abdelrazik et al., 2022). There is widespread consensus that addressing barriers to solar PV adoption remains a key step for improving rapid uptake (Abdelrazik et al., 2022; Chidembo et al., 2022a; Tang et al., 2022). However, research on solar PV barriers tends to (i) be homogenous, with a predominant focus on experiences of household non-adopters; (ii) overlook the influence of heterogeneity of income status on how barriers are experienced and glance over (iii) focus on experiences of solar PV adopters, and (iv) omit perspectives of key informants such as power producers and distributors, and energy experts.

Beyond environmental reasons for transition to renewable energy options such as solar PV, energy security is a key sustainability challenge, particularly in developing countries. Although households' access to energy is a basic human right (Rukshana et al., 2020; Coleman et al., 2023), more than 1.3 billion people globally have no access to electricity, and about a third of this group is found in Southern Africa (IEA, 2022). Electricity distribution companies, especially in developing regions, often find it very expensive to distribute electricity to both urban and rural areas due to low consumption rates (Gupta et al., 2021), and for those with access to electricity, affordability is a challenge (World Bank, 2019; Qin et al., 2022). For instance, developing regions such as sub-Saharan Africa and some parts of Asia face severe energy demand, which exceeds supply, thus contributing to serious energy shortages with socio-economic implications (IEA, 2021; 2022). Thus, most low-income households in these regions often rely on unclean forms of energy such as kerosene and coal (IEA, 2022). The World Health Organisation estimates that over 2.6 billion people rely on unclean sources of energy for domestic use, and these are linked to serious health effects, e.g., respiratory diseases

(Leary et al., 2021; IEA, 2023). These populations are characterised by energy poverty (the inability to afford or access clean energy), which negatively affects quality of life (Qin et al., 2022; IEA, 2023). This calls for just transitions to renewable energy, which can address the supply-demand gap, improve people's health, reduce socio-economic inequalities, and ultimately improve quality of life (IEA, 2023; Mirzania et al., 2023). Sustainable energy transition is not just a global imperative, but is very important for countries such as South Africa, which have a serious energy insecurity crisis and where the transition to renewable energy is at the centre of the country's energy transformation agenda (Eskom, 2023).

South Africa ranks among the top 20 emitters of carbon dioxide globally due to its reliance on coal as a primary source of energy (Calitz and Wright, 2021). The country's main energy producer and distributor, Eskom, contributes up to 42% of South Africa's total emissions, making it a major player in the country's environmental footprint (IEA, 2023). In addition, Sasol (a global chemicals and energy company) is the second-largest emitter in the country and the largest single-source carbon emitter in the world, with emissions exceeding those of at least 100 countries combined (Sguazzin, 2020; Eskom, 2023). The health impacts of these carbon emissions disproportionately affect South Africa's poor, considering the country has the highest levels of income inequality globally (Islam and Winkel, 2022; Khine and Langkulsen, 2023). Thus, the transition to renewable energy is not only driven by environmental factors but also social justice and economic imperatives – the notion of equal opportunities and access to resources, in this case, clean energy. For instance, solar PV adoption at a household level can directly benefit low-income households with reliable and cheap energy that ultimately benefits them financially. Apart from that, solar PV is mainly consumed at the point of generation. Thus, its adoption by households can reduce the cost of energy production, transmission, and distribution (Dippenaar et al., 2021). This could provide financial relief to South Africa's energy utility, Eskom, which is going through a financial crisis, and to municipalities that owe Eskom billions of rands in unpaid energy bills (Eskom, 2023). Many municipalities in South Africa are at risk of disconnection from the grid for non-payment, which has negative impacts on service delivery if a substantial portion of their revenues must be directed towards Eskom debt servicing instead of essential public services (Viljoen and Dube, 2023). Eskom's financial crisis has prompted the utility to increase tariffs to remain functional (Eskom, 2020). For instance, between 2007-2023 Eskom increased tariffs with up to 653% (Moolman, 2024). Moreover, power cuts, locally known as loadshedding, which started in 2008 and reaching a peak in 2023 have become a critical challenge in South Africa with no sustainable solutions in sight (Erero, 2023). However, in 2024, there has been a noticeable reduction in loadshedding, largely due to the rapid growth in solar PV adoption by large companies and high-income households (Ukoba et al., 2024). Which brings the question, why are low-income households not adopting solar PV which is partly the focus of this study.

In response to the energy crisis in South Africa, there are renewed and increasing calls for a shift to healthier and cleaner energy alternatives (Chidembo et al., 2022a; McKay and Hendricks, 2022). For instance, consistent with global estimates, there is an increased realisation of solar PV adoption among South African households as a cleaner and sustainable alternative to the inconsistent grid energy over the past decade (Akinbami et al., 2021; Statistics South Africa, 2024). Thus, the government, through the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), has initiated efforts to invest in renewable energy (IEA, 2022). Currently, solar PV has been adopted by close to 10% of households in South Africa (IEA, 2020). Through the REIPPPP, South Africa aims to install approximately 8,400 MW of solar PV by 2030 which has the capacity to electrify 1.5 million households across the country (IEA, 2022). Moreover, to address the impact of loadshedding, the government has also implemented a 10-point power crisis plan which liberalised the licensing processes for renewable energy generation (IEA, 2019; IEA, 2022). In addition, major South African banks such as Standard Bank, Nedbank, and Discovery Bank have started offering loans towards solar PV adoption. For instance, Standard Bank has initiated a bounce back loan guarantee scheme which offers up to ZAR 300 000 (US$15.617) for solar PV investments (Property Review, 2024). However, despite efforts by the government to invest in renewable energy sources such as solar PV, its rate of adoption is still very slow, contributing just 5% to the country's energy mix (IRENA, 2022).

Literature suggests that solar PV adoption among South African households is constrained by several barriers (Donev et al., 2012; Chidembo et al., 2022a; Chidembo et al., 2022b; Tang et al., 2022). These barriers include financial barriers such as high start-up costs and the availability of after sales maintenance support (Chidembo et al., 2022b; Tang et al., 2022) and lack of knowledge (Chidembo et al., 2022a; Chidembo et al., 2022b). Other barriers slowing down the adoption of solar PV among South African households point to institutional factors such as the non-availability of comprehensive feed in tariffs (Korsten et al., 2017) and underdeveloped policies (Lemaire, 2011; Donev et al., 2012). Though these studies are very important, they provide a limited understanding of the barriers and motivational drivers of solar

PV adoption across an income gradient. An exploration of barriers across an income gradient and stakeholders can provide insights into potential interventions for encouraging rapid uptake of solar PV energy by households across the income divide. Similar studies have been conducted elsewhere, for example, in developed economies like the US (Wolske et al., 2017) and Australia (Lan et al., 2020). However, the adoption of renewable energy policies, in general, and solar PV energy in particular, is varied across different countries as influenced by the different economic and policy environments (Wolske et al. 2017). In most developed countries, such as Australia (Lan et al., 2020) and Germany (Cheng et al., 2019), emphasis is on favourable feed-in tariffs, whereas at the local level, adoption can be shaped by household characteristics, market factors and economic conditions. Therefore, the various barriers to solar PV adoption reported across different global contexts highlight the need for empirical studies that examine these challenges within specific settings.

1.2. A just transition framework for identifying barriers to solar PV adoption

There is increasing recognition that investment in and the development of renewable energy can provide pathways to advancing sustainable development goals through the replacement of high carbon-producing fossil-based energy sources with clean, safe, and environmentally friendly alternatives (Ehresman and Okereke, 2015; Carley and Konisky, 2020; Wang and Lo., 2021). A just transition, in the context of renewable energy transition, refers to a process of moving towards cleaner, greener forms of energy in a way that is fair and equitable regarding aspects such as income, gender, and ethnicity (Lacey-Barnacle et al., 2020; McCauley and Heffron, 2018; Jenkins et al., 2016). The just transition framework covers broad areas, including recognition of the costs and risks of such transitions, including fossil-fuel job losses and declining revenue base from dwindling fossil-based revenues (Wang and Lo., 2021). Further, just transition concerns do not only relate to the loss of jobs related to the declining fossil-based industry but also to the distribution of the benefits of renewable energy. It is argued that the touted benefits of green renewable energy such as green jobs, might not benefit marginalised communities (McCauley and Heffron, 2018; Carley and Kosky, 2020; Wang and Lo., 2021). For example, literature reports an underrepresentation of people of colour in the US solar industry (Carley and Konisky, 2020). Further, due to the high costs of new renewable technologies, marginalised communities might not be able to afford the costs of purchasing renewable energy, leaving them to contend with rising electricity costs, which raises significant environmental justice (Carley and Konisky, 2020; Hess and Ribeiro, 2016) and energy poverty

(Kyprianou et al., 2019) concerns. Thus, if improperly conceived, the so-called ‘green’ renewable energy might result in new forms of exclusion and marginalisation of some demographic groups, which could exacerbate inequalities considering the already existing structural inequalities (Sovacool et al., 2019). Thus, the just transition conceptual framework has become one of the central pillars in renewable energy transition debates (Acheampong et al., 2023; IEA, 2023). Therefore, avoiding the perpetuation of energy injustice requires understanding barriers to adoption across differentiated demographic groups as a basis for developing interventions that ensure transitions can benefit all members of society.

Just transition debates are central, especially in developing countries such as South Africa which are characterised by significant socio-economic disparities and historical injustices (Acheampong et al., 2023; IEA, 2023). In essence, to achieve just transitions to renewable energy sources such as solar PV among South African households, debates need to be centred on addressing the uneven social and economic impacts of decarbonisation and ensure equitable distribution of benefits of renewable energy such as solar PV. Literature suggests that renewable energy technologies such as solar PV have the capacity to reduce institutionalised inequalities due to the decentralised and affordable access to clean energy they offer (Chidembo et al., 2022a; Eti et al., 2024). Literature from most developing countries, mainly in the Global South, has shown that barriers such as high capital investment needed for installation, lack of access to financial assistance, and lack of solar PV knowledge are the main barriers to solar PV adoption by households (Chidembo et al., 2022a; McKay and Hendricks, 2022). Though these barriers might affect both high- and low-income households, they have a disproportionate impact on low-income households due to their limited access to resources (Sustainable Energy Africa, 2019; Statistics South Africa, 2022). Thus, exploring the barriers and lived experiences of solar PV adopters and non-adopters in South African households can play a crucial role in supporting a just transition. For instance, the lived experiences of users can demonstrate how high-income households are better positioned to benefit from renewable energy incentives and subsidies, adding to the inequalities in energy transitions. For instance, there are several government programs supporting renewable energy transitions, such as the REIPPPP; however, it is important to assess whether benefits from these programs also trickle down to marginalised communities. Emphasis on the income gradient in the just transition debate accentuates such inequalities and strengthens the demands for targeted interventions. Therefore, an analysis of barriers to and experiences of solar PV across a differentiated income and stakeholder gradient should be seen as the first step towards a more holistic understanding of barriers needed to move towards objectives toward greater social justice outcomes in energy transitions.

1.3. Rationale of the study

This research provides insights into a broader understanding of how solar PV energy can be adopted and used as a cleaner and sustainable alternative to grid energy by shedding light on the social, economic, and environmental factors as well as the policy environment constraining the rapid and equitable adoption of solar PV in South Africa. Understanding the barriers to solar PV adoption is crucial for promoting the transition to renewable, clean, and green energy. Every country has unique contexts, including socio-economic differences and policy frameworks that shape these barriers and influence whether households adopt solar PV. This knowledge, in turn, can inform debates on the desired equitable energy transitions. To this end, the contribution of this study is twofold: First, it addresses the barriers to solar PV adoption across an income gradient in South Africa, a dimension that previous research, which tends to focus on homogenous demographic groups, has largely overlooked. To the best of our knowledge, this is the first systematic income group heterogeneity study attempting to understand solar PV adoption in South Africa. Secondly, the research enhances our understanding by drawing on the perspectives of key stakeholders (e.g., households, policy makers, solar PV installers, and energy distribution agents), whose insights are crucial but often underrepresented in research. A holistic view from all energy stakeholders is important as it provides perspectives and views from all key players such as adopters, non-adopters, and policy makers in generating information that can be used in the formulation of rational, inclusive energy transition legislation. By adding to the few existing local studies that focus on barriers and enablers separately, this work also explores the influence of values, socio-economic differences, and various motivational drivers of solar PV adoption among households. These drivers evolve with changes in the country's energy landscape. For instance, the persistent loadshedding experienced over the past decade could serve as a strong motivator for households to adopt solar PV as a primary energy source, rather than just a backup, as has often been presented in renewable energy studies in South Africa. Additionally, with international calls such as the Paris Agreement (2015) for a 1.6% annual decrease in emissions (Bekun, 2024), the South African government faces increasing pressure to identify cleaner alternative energy sources (Department of Energy South Africa, 2019). Thus, this study can help identify opportunities to support solar PV adoption and contribute to the energy security transformation, aligning with SDG 7 (affordable and clean energy) and SDG 13 (climate action).

Methodologically, this study uses a variety of approaches, namely scoping review, household surveys, and key informants' interviews to gather data on solar PV adoption in South Africa, using four towns in Eastern Cape province as case study towns - Gqeberha (formerly Port Elizabeth), East London, Makhanda (formerly Grahamstown), and Komani (formerly Queenstown). These above-mentioned methodological approaches were carefully selected to generate scientific data that can be used to both understand solar PV adoption barriers across different income gradients and to develop recommendations for achieving a socially just transition to solar PV adoption in South Africa.

1.4. Objective and research questions

The main aim of this study was to examine the barriers to solar PV energy adoption among South African households. Key questions guiding the study included:

1. What is the research progress and conceptual insights on barriers of solar PV adoption in South Africa?
2. What are the key barriers to solar PV adoption, and how do they vary between income groups?
3. What are the key primary motivational drivers and experiences of solar PV use among South African households?
4. What are key informants' views on the barriers to and policy options for solar PV energy adoption among households?
5. What are the implications of these findings on solar PV adoption debates and practice in South Africa?

1.5. Chapter outline

The thesis consists of six chapters, and out of these, four are research empirical chapters that have been prepared for submission to peer-reviewed scientific journals. For all the four research empirical chapters presented in this thesis, I (the PhD student and thesis author) assumed responsibility for conceptualisation, developing the methods and experimental designs, data collection, data analysis and write up. The supervisors contributed as co-authors on all research empirical chapters, implying they assisted in planning and offered constructive feedback for the different chapters – a similar role that is played by a PhD thesis mentor/supervisor. Given that this thesis comprises of research empirical chapters, co-authored by my supervisors, some sections of the chapters are presented using the first-person plural noun “we”, with the student (Uzziah Mutumbi) as the main and corresponding author for all the published and submitted chapters. The contributors of all empirical chapters either published or submitted for review are listed as U. Mutumbi, G. Thondhlana and S. Ruwanza. The thesis is organised as follows: Chapter 1 looks at relevant background information and gives a brief outline of the thesis. Chapter 2 is a scoping review of barriers to solar PV adoption in South Africa as a basis for advancing our understanding of the main barriers faced by households, as well as identifying gaps in literature and has been published in the journal outlet Heliyon. Chapter 3 examines barriers to solar PV adoption among high-income and low-income households in South Africa and is under review in the scientific journal Sustainable Energy Research. Chapter 4 examines the drivers and experiences of using solar PV among adopters for informing consumer demand side and is under review in the journal outlet Energy Reports. Chapter 5 explores key informants’ perceptions of barriers to household solar PV adoption to advance our understanding of barriers from multiple perspectives and to better inform interventions for rapid solar PV penetration among households. This chapter is written as a draft scientific paper that is ready for submission to a suitable scientific journal. Chapter 6 provides a synthesis of the study, suggests recommendations, and concludes. To maintain flow in reading and to avoid repetition, all references are attached at the end of the thesis.

CHAPTER 2: ADOPTION OF RESIDENTIAL ROOFTOP SOLAR PV SYSTEMS IN SOUTH AFRICA: A SCOPING REVIEW OF BARRIERS

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Abstract

Global sustainability challenges such as climate change are linked to carbon emissions from fossil fuel powered energy needed for commercial and household consumption. South Africa is highly dependent on coal for energy production; hence, the transition to renewable energy sources such as solar PV is seen as a pathway towards emissions reduction and a sustainable future. Yet, despite the huge potential for solar PV technologies, adoption remains very low. This scoping review examines the barriers to household solar PV adoption in South Africa to advance our understanding beyond case study level studies. We analysed all published literature on household solar PV in South Africa as a basis for finding themes, gaps, and trends on solar PV research. Review results show that key barriers can be grouped into financial, personal, institutional, technical, and societal barriers, however there were no studies on barriers across an income gradient, a glaring omission given debates on just transitions. Given the complexity of the barriers ranging from personal, societal, to technical barriers, it is not reasonable to expect the government to facilitate transition to solar PV alone. Rather, collective approaches are needed to create enabling conditions for solar PV adoption, such as the financial means and information availability. The private sector has a key role to play either in supporting state-initiated programmes or creating the means for solar PV adoption, such as power purchase agreements. That said, the state remains a central player in facilitating an enabling economic and political environment to leverage responsiveness from other actors. Without an integrated approach to addressing barriers to solar PV adoption, solar PV adoption will remain a source of energy for the economically privileged, and the imperative to just transition to renewable energy a pipe dream, in a country characterised by large inequalities among households.

Keywords: Adoption; Barriers; Consumption; Households; Renewable energy; Solar PV.

2.1. Introduction

Globally, the transition to renewable energy sources is rapidly growing in response to global energy crisis and sustainability imperatives (Xue et al., 2021; Szetela et al., 2022). Among renewable energy sources solar photovoltaic (PV) systems are rapidly growing in demand due to multiple factors including decreasing prices and considerable return on investments (Xue et al., 2021). Further, geopolitical factors have negatively impacted the price of fossils fuels such as coal, petroleum, and gas, making dependence on fossil fuels for energy expensive and insecure (Xue et al., 2021). For instance, the emergence of the Russian-Ukrainian war resulted in a sharp increase in crude oil by over 50 % in 2022 (IRENA, 2022; United Nations, 2023), translating into high fuel and energy prices as well as increased cost of living (Smirnova et al., 2021; Mutumbi et al., 2022). Generally, the price of energy sources from fossil fuel is on the increase thus the need for cheaper and affordable alternatives such as solar PV. Solar PV energy which is based on technology that converts sunlight into electrical energy is considered a cheap, reliable, profitable and clean energy source with low maintenance costs and a long lifespan (Fan and Zhou, 2022; Zhu, 2023; Gao and Zhou, 2023). The environmental benefits of solar PV adoption are arguably centred on carbon emission reduction from reduced coal use (Szetela et al., 2022; Stern et al., 2022). For example, previous studies have shown that solar PV adoption in Germany has reduced carbon emissions levels by more than 40 % compared to 1990 levels (IRENA, 2022). The bulk of these carbon emissions are at household level because households are a major consumer of energy (Abrahamse and Schuitema, 2020; Mutumbi et al., 2022), thus the need to start investing in household solar PV energy (IRENA, 2022).

However, the indirect environmental benefits are substantial, including reduced biodiversity loss and land degradation associated with open cast mining (Zhang et al., 2019; Sonter et al., 2020; Yang et al., 2024) and other downstream benefits beyond the mining site such as reduced water pollution and stream sedimentation. At the same time, although solar PV systems are recognised as a pathway towards halting climate change, there are environmental and equity concerns relating to renewable energy initiatives (Gao and Zhou, 2022; Fan and Zhou, 2023). For example, Sonter et al. (2020) caution that the technology and infrastructure needed for renewable energy production will lead to high demand for metals, which might rigger new mining ventures. Other environmental concerns of solar PV systems relate to manufacturing processes and disposal of hazardous substances, leading to land and water pollution (Tawalbeh et al., 2021). Nonetheless, the environmental impacts are still considered minimal relative to fossil fuel energy sources, and future efforts on solar PV design improvements, sustainability and recycling might mean that the impacts will become less concerning (Szetela et al., 2022; Stern et al., 2022). Generally, the benefits of transitioning to renewable energy sources like solar PV seem to outweigh the costs, however, consistent with just energy transition debates, questions over who benefits from renewable energy are gaining traction with a view to avoiding the marginalisation of low-income households in renewable energy access (Sanusi, 2019; Ngarava et al., 2022). For example, in South Africa, inequalities in access to renewable energy among marginalised communities have been reported in energy justice debates (Monyai et al., 2023; Masuku, 2024). Also, in Germany monopolistic power distribution companies are responsible for setting prices of renewable energy that households sell into the energy grid, thus negatively affecting solar PV adoption if prices are not favourable (IRENA, 2022).

Developed countries such as Australia and Germany have made some considerable strides in the adoption of solar PV (IEA, 2022). For instance, in Australia solar PV now provides up to 20 % (6600 MW) of energy to households (IEA, 2022), whereas in Germany, estimates suggest that solar PV contributes around 10.5 % (around 15 TWh) annually to the country's energy mix (Gao and Zhou, 2022). In contrast, solar PV uptake in Africa remains low, yet the bulk of the African population does not have access to grid energy. For example, Burkina Faso has the lowest rate of grid connectivity with approximately 69 % of the population without access to the national energy grid (IEA, 2022). African countries also face poor energy delivery, as most power utility firms are unable to meet the rising demand for energy, resulting in power outages which result in negative socio-economic impacts (Bwalya et al., 2022) and mental health impacts (Lin and Okyere, 2020). For instance, Bwalya et al. (2022), reported evidence of socio-spatial segregation in metropolitan settings in Zambia, with poorer residential areas suffering disproportionately negative effects of loadshedding compared to wealthy residential areas. These above-mentioned scenarios in Africa point to the need for investment in solar PV, both as a cheaper energy source and a means to provide energy for basic needs to the greater population. Interestingly, most African countries have climatic conditions favourable for solar PV adoption, yet they continue to lag. For instance, more than 80 % of the continent's landscape receives close to 2000 kWh/m2 with most Southern African countries receiving an estimate of about 6 kWh/m2 (United Nations, 2023). Despite these opportunities being available for solar PV adoption in Africa, efforts towards solar PV adoption remain slow (Aliyu et al., 2018; Bwalya et al., 2022; Mirzania et al., 2023).

The abundance of sunlight in Africa, coupled with the constant decrease of solar PV unit prices, makes the continent an ideal destination for solar PV energy generation (IRENA, 2022; Bwalya et al., 2022). Globally, several studies have outlined some of the barriers preventing solar PV adoption (Khattak et al., 2006; Dagnachew et al., 2020; Abdelrazik et al., 2022). Generally, the most identified solar PV barriers are financial, personal, technical, and institutional barriers (Jacobsson and Lauber; 2006; Sovacool et al., 2011; van Norden, 2015; Vasseur and Kemp, 2015; Qureshi et al., 2017). In general, barriers are factors or circumstances which prevent a person from accessing or using a desired service of interest. Financial barriers are money related factors that prevent access to solar PV. For example, the lack of pricing benchmarks for solar PV systems, which leads to high start-up costs has been reported in Pakistan (Khattak et al., 2006) and German (Jacobsson and Lauber, 2006) as a key solar PV financial barrier. Personal barriers relate to factors that are personal to an individual that act as a hindrance to solar PV adoption. For example, lack of knowledge by adopters which lead to misconceptions and failure to operate and maintain the solar PV systems were reported in Netherlands (Vasseur and Kemp, 2015) and Bangladesh (Thiam, 2011; Sriwannawit, 2014) as key personal barriers to solar PV adoption. Literature also reports on technical barriers which are solar PV related technological factors that hinder use and adoption. For example, the lack of access to solar PV technology, manufacturing industries, service parts, and human technical expertise to install and maintain solar PV system has been cited in most developing countries as a key technical solar PV adoption barrier (Jadhav et al., 2017; Dagnachew et al., 2020). Institutional barriers relate to policies, laws, procedures, and situations that disadvantage solar PV users. For example, studies in Australia (Lan et al., 2020) and Malaysia (Ahmad et al., 2015) report that the reason why solar PV adoption was slow among households was due to the lack of comprehensive policies and feed-in tariffs. Besides these above-mentioned broad barriers, Lo et al. (2018) indicated that barriers to solar PV adoption are complex, meaning they should be understood from a sociotechnical approach. This implies that barriers such as technical, social, economic, cultural, political, and historical factors could affect transition to solar PV individually or in combination. The study by Lo et al. (2018) listed barriers based on the following categories; technical and environmental, economic and financial, market, policy and regulatory barriers. Regardless of how barriers to solar PV are categorised a systematic understanding of solar PV barriers in Africa, particularly amongst South African households is lacking. The adoption of solar PV systems in South Africa is urgent due to several factors. Firstly, the energy tariffs in South Africa continue to increase beyond the reach of many poor households (Eskom, 2020). Although these energy tariff increases are meant to intensify energy generation capacity to meet demand and are also aimed at solving Eskom's financial challenges (Eskom, 2020). Between 2022 and 2023, the National Energy Regulator of South Africa (NERSA) approved about 18.7 % increase of energy tariffs, which negatively affects households, particularly those from low-income groups (Eskom, 2023). Secondly, South Africa is currently experiencing a shortage in energy supply as evidenced by constant loadshedding. The effects of loadshedding are mostly felt by households and small businesses who do not have alternative forms of energy (Calitz and Wright, 2021), thus solar PV adoption could be a solution for them. Thirdly, the bulk of South Africa's energy is from fossil fuels, with about 95.6 % coming from low quality coal (Eskom, 2020). The use of fossil fuels contributes up to 42 % of the country's carbon emissions, which is likely to have negative consequences on the environment (Eskom, 2023). Hence, the transition to solar PV is necessary if South Africa is to meet its international environmental climate change targets of reducing global warming to 1.5 ◦C (IEA, 2019). Lastly, besides the residential sector in South Africa being one of the biggest consumers of energy, it is also the biggest carbon emitter, requiring the transition to solar PV for carbon emission reduction (Ivanova et al., 2016; IEA, 2019; IEA, 2020)

Efforts towards solar PV adoption are underway in South Africa, although the pace is generally slow (Calitz and Wright, 2021). Firstly, the country initiated the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) aimed at increasing energy capacity through private sector investment in solar PV. To date solar PV projects have increased with close to 10 % of households having adopted solar energy for their day-to-day use (IEA, 2020. Under REIPPPP, South Africa aims to install a solar PV generation capacity of about 8400 MW by 2030, a capacity that would benefit about 1.5 million households (IEA, 2022). Secondly, to mitigate the impact of power outages, the South African government outlined a 10-point power crisis plan which amongst other things deals with licensing of energy generation. For example, the government waived the private power generation licensing requirements from 1 MW to 100 MW to allow independent power producers to generate more renewable energy (IEA, 2019; IEA, 2022). Thirdly, the South African government is working towards enacting policies that are favourable for solar PV adoption. For instance, with effect from March 2023, rooftop solar panel installations are now eligible for tax refunds of up to 25 % of the cost of the panels (IEA, 2022). Despite these supportive measures, the rate of solar PV adoption is still very low particularly by low households. Identifying and understanding barriers to adoption can help inform interventions for addressing the barriers and encouraging rapid intake of solar PV systems by the residential sector. Moreover, an understanding of the socially-embedded structural barriers that can perpetuate inequality in renewable energy is required for just energy transition. South Africa is a country that has high unemployment rate (Calitz and Wright, 2021) and most households cannot afford solar PV systems. Therefore, this scoping review is motivated by the need to provide a comprehensive review of empirical studies on South African residential solar PV to gain insights into barriers affecting solar PV adoption. A review of barriers across a household income gradient can help policy makers to understand and address these barriers in equitable ways.

2.2. Methodology

We adopted a scoping review approach to identify barriers to household solar PV adoption in South Africa based on literature published between 2000 and 2023. Scoping reviews give a general overview of a field of study to determine the volume of literature and existing knowledge gaps (Cooper and Schindler, 2013). Hence, in this research, literature was evaluated based on the extent of household solar PV search available and its focus, with reference to barriers of solar PV adoption among South African households. The scoping review was structured following the Reporting Standards for Systematic Evidence Syntheses (ROSES) which is a pro-forma flow diagram and a descriptive summary of the plan and conduct of environmental systematic reviews (Haddaway et al., 2018). The ROSES provide a gold standard which assists reviewers with rich instructional information aimed at achieving certain levels of rigor (Haddaway et al., 2018). In March 2022, the first author, with the help of a professional librarian commenced the initial search of literature. Papers were thoroughly and methodically searched using popular databases namely Scopus, Web of Science and Google Scholar, which are the most extensive databases comprising book chapters, books, journal articles and conference proceedings (Gray et al., 2012). The databases cover a wide range of disciplines including humanities, physical sciences, biological sciences and social sciences (Falagas et al., 2008). The limitations of Google Scholar as a trustworthy source for reviews are recognised (Falagas et al., 2008; Gray et al., 2012), especially its usage as the main search engine (Gusenbauer and Haddaway, 2020). Key limitations include that some of the items retrieved in Google Scholar are not peer reviewed while the search engine has restrictions on subject indexing which can limit the findability of pertinent items (Falagas et al., 2008). Even though Google Scholar has restrictions, it offered relevant papers that were unavailable in other databases, as observed elsewhere (Gusenbauer and Haddaway, 2020). All authors actively collaborated in crafting the search string, guided by a professional librarian from the Rhodes University library. The key search terms were categorised into three sections namely the focus area, keywords and search-scope (Table 2.1). The same key search terms were used on all the three databases following method employed by Ghaboulian-Zare et al. (2021).

Table 2.1. Key search terms.

Focus area	Keywords	Search scope
Household	House* OR home* OR resident* OR dwelling* OR domestic ("Solar photovoltaic" OR "solar PV" and "South Africa")	Topic
Adoption	Adopt* OR diffusion OR uptake OR "take up" OR acceptance OR motiv* ("Solar photovoltaic" OR "solar PV" and "South Africa")	Topic (title-abstract-keywords)

2.2.1. Scope and exclusion criteria

Exclusion keywords are used in scoping reviews to judiciously narrow the search findings to meet the scope (Aitken et al., 2016; Ahmed et al., 2022). All the three authors actively participated in developing the exclusion criteria. Articles that were clearly related to the subject of the study were carefully selected and analysed. The goal was to compile the most recent and most relevant articles that had been published, which included works from January 1, 2000 to December 2023. All articles which were not focused on the barriers of solar PV were excluded in the analysis as suggested by Ahmed et al. (2022). Article titles and abstracts were used to thoroughly screen the articles, and those that were not relevant were removed.

2.2.2. Eligibility of articles

To assess eligibility, each article's full text was retrieved based on titles and abstracts and were then read (Figure 2.1). To avoid leaving out relevant articles, references of the included articles were analysed to check for articles that may have been omitted by the three databases. Unpublished material, editorial notes and non-English publications were also excluded from the analysis. The potential limitation of the study is that it only considered articles written in the English language, which might have resulted in omission of relevant articles in other languages such as French. Nevertheless, given that English is the widely used medium of instruction in published South African literature, we do not think the language bias has huge implications for our analysis.

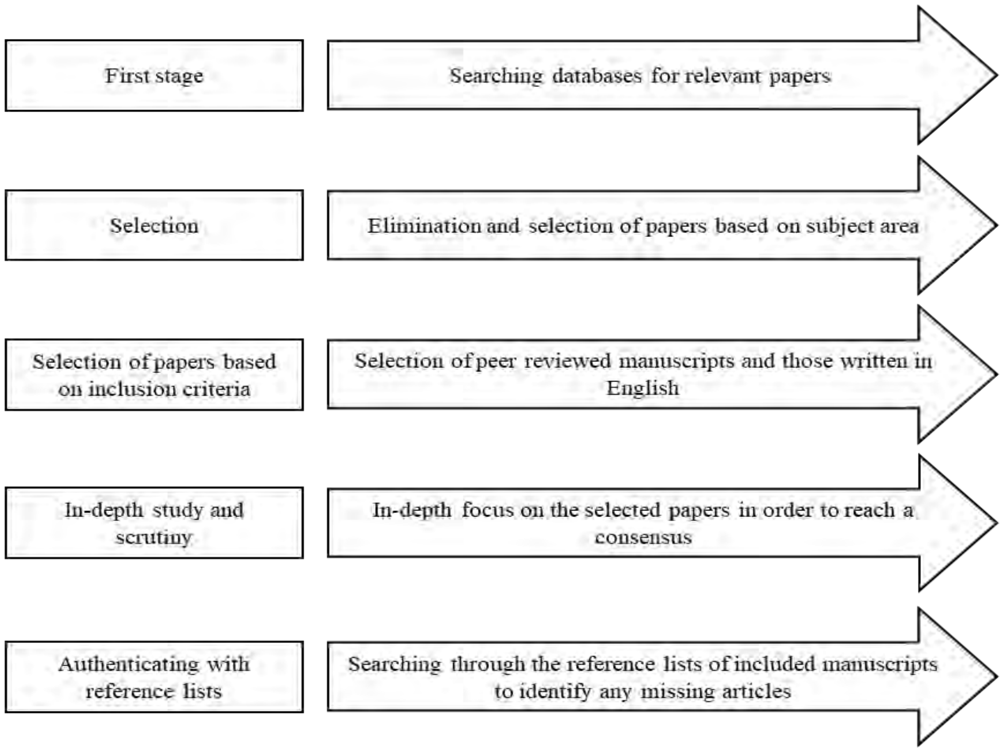

Figure 2.1. Eligibility criteria of articles (Ghaboulian-Zare et al., 2021).

The first phase of the search returned 857 articles, however, after removing duplicates (532) and irrelevant articles based on title and area (e.g., non-South African papers = 55), only 270 articles were returned (Figure 2.2). Duplicates were eliminated using Zotero software by adding the downloaded articles to the Zotero database which identified, highlighted, and removed repeated articles. A subsequent manual check was performed by all the authors to ensure thorough duplicate removal. After reviewing the abstracts, a further 237 articles were excluded for not meeting the criteria, leaving 33 articles. For instance, after reading the abstracts we note that a substantial number of articles focused on Concentrated Solar Power (CSP) while others focused on microgrids and mini grids and other non-residential sectors such as universities, industries, and businesses. The full text screening excluded an additional 16 articles since they were outside the scoping review focus. Therefore, 14 articles were returned because they focused specifically on the barriers to household solar PV in South Africa. After examining the remaining publications' reference lists, four more articles were added resulting in 18 being considered for the scoping review (See appendix 2.1). The steps and procedure used to gather articles for the scoping review are summarised using the ROSES search chart (Figure 2.2).

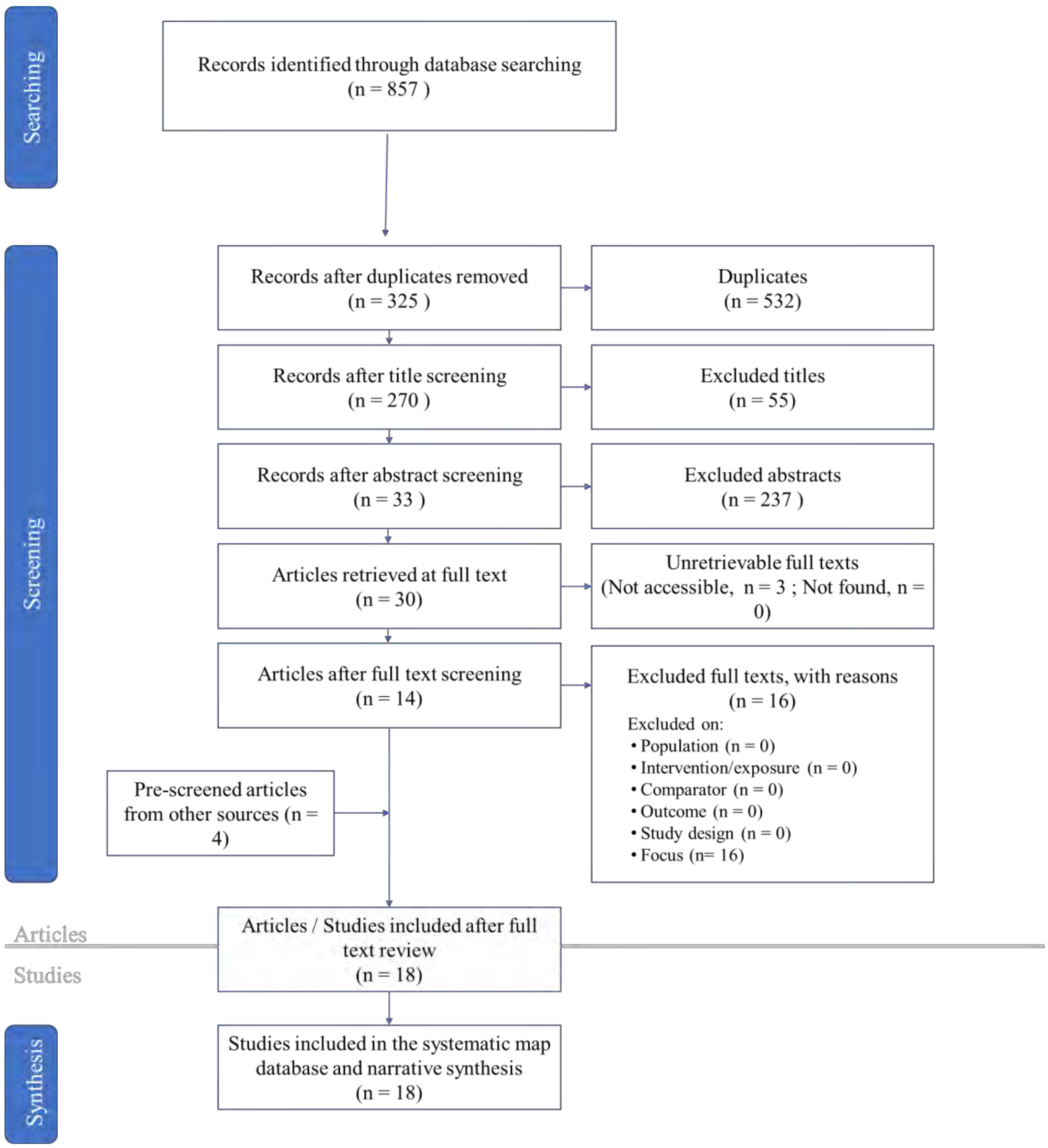

Figure 2.2. The ROSES search chart.

2.2.3. Data analyses

The research employed an inductive methodology, meaning that the research themes were not pre-selected and examined but emerged through the examination of pertinent articles following suggestions by Gusenbauer and Haddaway (2020). Thematic codes were created after multiple iterations of preliminary reading of the chosen publications, and the papers were then grouped into work packages in accordance with the theme codes to enable quantification of the results. As in most global solar PV literature, the packages included financial, technical, institutional, personal, and social barriers (Khattak et al., 2006; Qureshi et al., 2017; Dagnachew et al., 2020; Abdelrazik et al., 2022). The distribution of articles was displayed descriptively using proportions and histograms based on the publishing type (grey literature including theses or journal articles), publication year, and the conceptual emphasis of the articles.

2.3. Results and discussions

2.3.1. Barriers to solar PV adoption among households

Review results show that 61 % (n = 11) of the reviewed articles focused on financial barriers ranging from high start-up costs and non-availability of bank loans to support solar PV adoption (Bikam and Mulaudzi, 2006; Chang et al., 2011; Lemaire, 2011; Adams, 2012; Hendricks, 2016; Conway et al., 2019; Tlhatlha, 2020; Chidembo et al., 2022a; Chidembo et al., 2022b; Tang et al., 2022; McKay and Hendricks, 2022) (Figure 2.3). Similarly, 61 % (n = 11) of the articles (Bikam and Mulaudzi, 2006; Lemaire, 2011; Chang, 2011; Adams, 2012; Hendricks, 2016; Curry et al., 2017; Thobejane et al., 2019; Tlhatlha, 2020; Chidembo et al., 2022a; Chidembo et al., 2022b; McKay and Hendricks, 2022) focused on personal barriers to solar PV adoption including lack of knowledge on how to operate the solar PV systems and dissatisfaction with the solar PV output quality. Half of the articles 50 % (n = 9) (Bikam and Mulaudzi, 2006; Lemaire, 2011; Donev et al., 2012; Azimoh et al., 2015; Hendricks, 2016; Tlhatlha, 2020; Chidembo et al., 2022a; Chidembo et al., 2022b; McKay and Hendricks, 2022) reported institutional barriers ranging from lack of government and utilities support as to lack of grounded policies which can incentivise the adoption of solar PV among households. Only four articles (22 %) reported technical barriers - the lack of technical expertise to install and operate solar PV systems and non-availability of spares to repair faulty systems (Bikam and Mulaudzi, 2006; Azimoh et al., 2015; Kritzinger and Covary, 2016; Thobejane et al., 2019). The least number of articles (17 %, n = 3) focused on societal barriers which were mainly related to theft of solar PV systems (Bikam and Mulaudzi, 2006; Azimoh et al., 2015; Chidembo et al., 2022a).

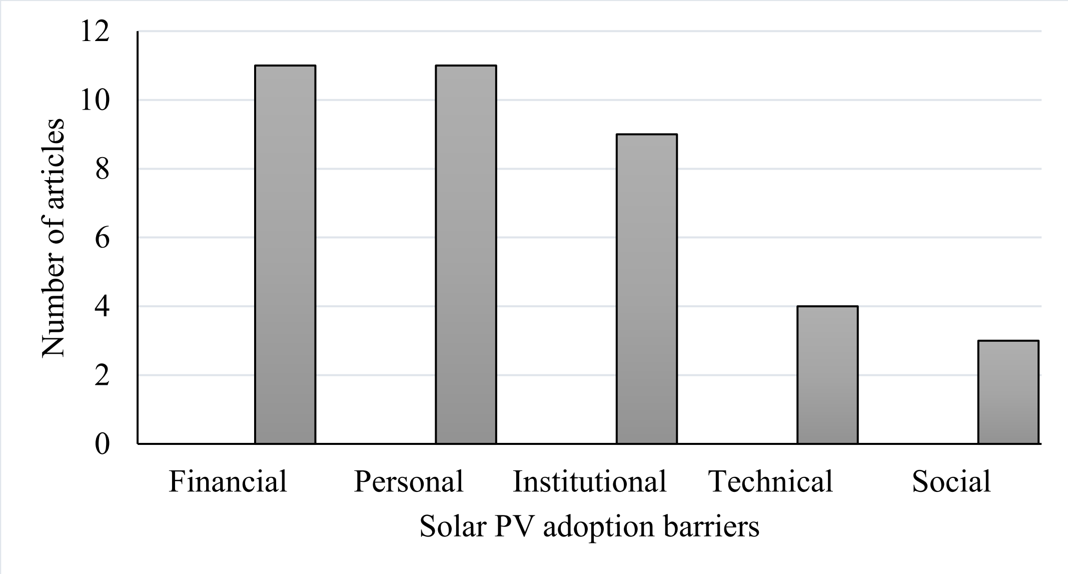

Figure 2.3. Types of solar PV adoption barriers identified in South Africa.

Financial barriers

A key financial barrier to solar PV adoption by households relates to high start-up costs and the availability of after sales maintenance support (Chang et al., 2011; Hendricks, 2016; Conway et al. 2019; Chidembo et al., 2022a; Chidembo et al., 2022b; Tang et al., 2022). For instance, in a study exploring the hybrid models for comprehensive access to basic energy among informal households in Zimbabwe and South Africa, Conway et al. (2019) found that solar home systems that are not subsidised have a lower chance of being accepted especially by marginalised societies because they are costly to purchase and maintain. Similar findings were also reported by Chidembo et al. (2022b) who found that most rural households in the Vhembe district of South Africa were reluctant to adopt solar PV because of the high capital investment needed but beyond the reach of many households. Hendricks (2016) studied the determinants of solar PV adoption among high-income households in Parkhurst Johannesburg and found that they considered rooftop solar PV initiatives very expensive, and the investment to provide very slow and low returns. Parkhurst residents also felt it was not possible to include the cost of solar PV instalment in selling value of their property if they considered selling which constrained their willingness to adopt solar PV (Hendricks, 2016). Similar perceptions were reported by Chang et al. (2011) and Tang et al. (2022) who found that most South African households perceived the adoption of solar water heaters as costly and could only be achieved through government interventions such as donations or subsidies. Such government initiatives include the Solar Water Heating Rebate Programme which provides low-income households with access to hot water (Parsad et al., 2020). However, Chang et al. (2011) and Tang et al.

(2022) noted that the number of existing government initiated solar PV subsidy programs in South Africa were not sufficient to support meaningful solar adoption. The consensus among studies on financial barriers is that solar PV is an expensive initiative which needs the intervention and support of governments to spearhead its adoption, especially among marginalised and low-income groups of households.

Barriers pertaining to high capital investment of solar PV have also been reported elsewhere. For instance, in Pakistan, Khattak et al. (2006) report that market structures with no market control pricing benchmark resulted in high start-up costs which were beyond the affordability of many households. Studies in Germany Jacobsson and Lauber (2006) and Netherlands (Vasseur and Kemp, 2015) have found that economic feasibility is one of the major factors hindering households' decision to move to solar PV. A study in India showed that more than 45 % of Indian households were failing to adopt solar PV due to cost related reasons (Parsad et al., 2020).

Other financial barriers relate to the lack of credit facilities to promote solar PV purchases. Studies by Chidembo et al. (2022a, b) which reviewed the determinants of solar PV adoption among rural households in South Africa found that most rural households did not have a consistent income, hence, they did not have the disposable income to purchase solar PV systems. Further, most rural households did not have collateral security to get loans from banks for solar PV purchase. Similar sentiments were reported by Lemaire (2011) who suggested that the low adoption of solar PV initiative in South Africa is due to the lack of financial arrangements between households and institutions that provide financial assistance for purchasing solar PV technology. Hendricks (2016) argues that banks and other financing facilities generally take a conservative approach which leaves out marginalised households and societies when they provide funds for initiatives such as solar PV in South Africa.

Issues related to lack of credit facilities as a solar PV adoption barrier have also been reported in other countries, e.g., among US low-medium income households (Cook and Bird, 2018). The above-mentioned study found that most low-to medium income households among the US household were typically excluded from financial arrangements for supporting solar PV adoption because they had low credit scores (Cook and Bird, 2018). However, the same study also reported that few households with high credit scores were financially excluded from solar PV loans due to debt from cars loans and house mortgages (Cook and Bird, 2018).

These findings suggest that, financial barriers relating to solar PV installation remain one of the main reasons behind low solar PV adoption among households of varying economic status, though the marginalised households are likely to be disproportionately affected. These findings also suggest that policies supporting solar PV should be directed around regulating market structures so that solar PV products are not too expensive to purchase. Such initiatives have been implemented with success in the US, where the Solar Energy Technology Office (SETO) has set a benchmark guiding solar PV market to promote the adoption process among industries and households (SETO, 2021). A study in Seychelles reported a high solar PV adoption (>40 %) rate and attributed it to financial support in the form of credit facilities (Etongo and Naidu, 2022). This implies that solar PV adoption among households is expensive and may require financial support from credit facilities if solar PV adoption is to increase in less developed countries.

Personal barriers

Two key personal barriers were identified namely, lack of knowledge and personal satisfaction. Slightly below half of the articles (44 %) point to the lack of knowledge and skills needed to operate and repair faulty solar PV equipment as contributing to the low adoption of solar PV among South African households (Bikam and Mulaudzi, 2006; Lemaire, 2011; Adams, 2012; Hendricks, 2016; Curry et al., 2017; Thobejane et al., 2019; Chidembo et al., 2022a; Chidembo et al., 2022b). For instance, Bikam and Mulaudzi (2006) found out that one of the factors which led to the failure of the solar energy pilot project in Folovodwe, South Africa was that households were never equipped with the skills to operate and maintain the solar PV systems, leading to lack of interest and dissatisfaction among households. Thobejane et al. (2019) found similar observations in a review of the factors behind failures in the rolling out of solar geysers among South African households. They found that most solar geyser recipients were neither trained nor received any form of information on how the systems functioned, which resulted in wrongful use and ultimate damage to systems. A similar study of residential solar PV panels installed by international donors found that the solar PV panels were abandoned a few years after they were installed, simply because the recipients lacked knowledge, skills, and understanding of how the systems work (Lemaire, 2011). Curry et al. (2017) also report that solar geyser owners in the Tshwane district of South Africa lacked knowledge on how the system worked, leading to underuse and dissatisfaction. Chidembo et al. (2022a, b) also observed that solar home systems were not adopted as expected in South African households because the users lacked knowledge on how the systems functioned and could not determine its potential risks and benefits. This lack of knowledge, in turn, leads to wrongful use resulting in negative attitudes when solar PV systems fail to meet the expected output. In a study by of solar PV systems in Parkhurst, Johannesburg, Hendricks (2016) found that, householders were generally skeptical of roof top solar PV because they were not fully informed about how the systems functioned and did not trust the suppliers. In light of knowledge barriers, Adams (2012) argues that households should be educated about the benefits, functions, downslide of solar PV systems to allow them to make informed decisions about purchasing the solar PV systems, emphasising that knowledge of the systems can help potential consumers to ascertain the risk and the potential benefits.

Barriers relating to knowledge are quite prevalent among developing countries which are known to have limited resources to initiate solar PV knowledge and skills transfer programmes to the public (Sovacool et al., 2011; Ohunakin et al., 2014). Thus, it is worth noting that until households are properly informed about the pros and cons as well as the technical aspects of solar PV technology, supportive efforts for the diffusion of solar PV systems might not yield optimum results. Hence, it is plausible in the South African context to argue that the government and key solar PV stakeholder like private companies need to direct more effort on educating households on solar PV systems functionality, particularly low-income households that often have limited access to such information. This could be in the form of awareness campaigns using existing community meeting forums and social media or through the school curriculum. For example, in the US, the Solar Energy Technologies Office (SETO) - a branch in the Department of Energy, launched a successful inclusive solar awareness campaign which sought to encourage solar adoption across a diverse audience (US, Department of Energy, 2022). The United States is also committed to advancing solar energy education through the creation of a comprehensive set of K-12 curriculum resources, assistance for outreach coordinators and teachers in implementing modules and lessons on solar PV science and engineering (Jordan et al., 2019). Similar initiatives can be implemented in South Africa through the Science, Technology, Engineering and Mathematics (STEM) education initiative, where solar PV studies can be integrated into the curriculum starting from elementary stages of learning.

Apart from lack of knowledge, dissatisfaction with the quality of solar energy was also reported as a key personal barrier to solar PV adoption (Adams, 2012; Azimoh, 2014). For instance, Azimoh (2015) found that households that were not connected to the grid and were put on the government solar PV scheme ended up shunning solar PV systems for fear of being pseudo-connected which could risk their exclusion from the perceived more reliable and efficient energy grid energy. The dissatisfaction relates to the quality of energy produced by solar panels as it could not support other household energy needs such as cooking and refrigeration. Adams (2012) has also reported customer dissatisfaction as a barrier, describing renewable solar PV energy systems as a relatively new system whose rate of assimilation is solely dependent on customer satisfaction. A World Bank report similarly concluded that most South African solar PV recipients and adopters were dissatisfied with the systems due to its limited capability to support key household energy requirements (IEA, 2022). Elsewhere, a study among Indian rural households found that solar PV performance had a significant positive impact on households' satisfaction (Prajapati, 2022). Thus, solar PV suppliers and installers need to assess the energy needs of households to match them with the capabilities of solar PV systems. Further, information provision should include details about the size of solar PV systems needed to support household energy needs before the installation process starts. When households are equipped with enough information related to solar PV capacity, they can make informed decision about the solar packages that satisfies their needs. Kumar et al.'s (Kumar et al., 2019) study on Indian solar customers, shows that pre-sales services ensured that consumers obtained comprehensive information about solar products as including operating principles, operational needs, advantages and disadvantages, usage restrictions, appliance efficiency, and quality principles.

Institutional barriers

Institutional barriers reported in the reviewed studies include lack of support in the form of feed in tariffs from local municipalities and the main power utility, Eskom (2020; 2023). The lack of support could be attributed to the fact that both municipalities and Eskom generate their revenue through selling conventional grid energy, hence, a transition to solar PV could compromise their income. For example, a study on the impact of grid connected solar PV on municipal revenue in Stellenbosch, found that municipality would lose about 0.6-2.4% in revenue, if households transitioned to solar PV (Korsten et al., 2017). Municipalities in South Africa are responsible for selling about 40 % of energy and as part of diversifying the energy mix, efforts have been made to purchase energy from rooftop house-owners (Kritzinger et al., 2020). However, households expect municipalities to pay the same amount of money they pay for energy which could leave municipalities with no profits (Kritzinger et al., 2020). Hence, it plausible to argue that the limited support from local municipalities to support the transition to solar PV among households is linked to potential losses. Lack of institutional support from the government and companies that supply energy has also been reported in Japan, where monopolistic companies which sell energy do not prioritise renewable energy sellers as they compromise their fossil energy sales (Bermudez, 2018). Elsewhere, the imbalance resulting from the feed-in tariff policy has also been reported (Winter and Schlesewsky, 2019). For instance, in Germany, the feed in tariff policy has been so successful that it now threatens the financial viability of the energy providers (Winter and Schlesewsky, 2019). Hence, energy providers should ensure that there is a balance between their energy supply and households' independent generation of renewable energy, for a mutually beneficial transition.

Other institutional barriers that were identified relate to inconsistent and under-developed policies on solar PV adoption within South Africa (Bikam and Mulaudzi, 2006; Lemaire, 2011; Donev et al., 2012). For instance, Donev et al. (2012) suggest that the low adoption of solar water heaters results from lack of grounded renewable energy policies that foster adoption, describing the South African renewable energy policies as weak and dominated by conventional energy policies with little or no support for solar PV transition. For example, in 1999 the South African government launched a solar electrification programme called a Fee for Service Concession where it distributed solar PV systems in return for a very small monthly payment which was specifically directed towards maintaining the systems (Lemaire, 2011). Lemaire (2011) reported that the above-mentioned programme failed due to lack of an effective and transparent renewable energy policy. In addition, there were no guiding principles for dissemination such that the solar PV systems were allegedly distributed based on political affiliation. The lack of feasible policies for guiding adoption has also been reported by Bikam and Mulaudzi (2006) who found that solar energy pilot project in Folovodwe failed because it was not guided by the cultural dynamics of the households. For instance, the local communities were culturally connected to traditional energy sources such as coal and firewood, which constrained adoption of solar PV systems (Bikam and Mulaudzi, 2006). Lack of policies that support transition to solar PV has been reported somewhere (Zhang and He, 2013). In Malaysia, lack of strong policies in solar PV transition explain the slow adoption by households of solar PV (Ahmad et al., 2015). However, policy successes have been noted in Germany (Jacobsson and Lauber, 2006). If the South African government is to succeed in just transitions to solar PV, there should be a shift in policy support from conventional to renewable energy policies (Department of Energy, S.A, 2019). The country lacks grounded national policies which frame residential solar PV. Interestingly, the persistent power outages in South Africa have seemingly forced the government to develop and implement solar PV policies that could facilitate solar PV transition (Energy Central, 2022). For example, the introduction of tax rebates linked to solar PV installation by households (South African National Treasury, 2023) is a welcome policy that could incentivise households to adopt solar PV. Although policies on selling excess solar energy to the conventional grid are now in place, some experts think the policy is still costly for many households as they are required to pay tax to sell back to grid (Githahu, 2023).

Another institutional barrier reported relates to grid encroachment, which happens when conventional grid energy is introduced in areas that have been targeted for solar PV, thus slowing down the adoption process. Chidembo et al. (2022b) found that the grid expansion into areas targeted for solar PV was one of the main barriers to solar PV adoption in rural South African households. This is mainly because grid energy is usually government-funded and hence it is cheaper for low-income households. The impact of cheaper forms of conventional energy relative to solar PV adoption has also been reported to slow down the transition to solar PV in Nigeria (Ohunakin et al., 2014), Sweden (Palm, 2018) and United States (Rai and Beck, 2015). This implies that households may be more concerned with affordability and access to energy than about the environmental impacts of the energy source.

Technical barriers

Technical barriers such as technical faults and non-availability of solar PV systems maintenance were identified by Bikam and Mulaudzi (2006), Curry et al. (2017) and Aigbavboa (2015). For instance, in Folovodwe, South Africa, a high rate of breakdown on the solar PV systems due to wear and tear was reported and non-availability of spare parts was the key factor behind the unsuccessful implementation of a solar PV pilot project (Bikam and Mulaudzi, 2006). The spares had to be imported, which was very expensive and time consuming for households. Another pilot solar water heater project in the city of Tshwane, South Africa reported similar findings, where technical faults and non-availability of spare parts prevented the project from achieving its desired results (Curry et al., 2017). Technical barriers have been reported in other countries, particularly in developing countries such as Guinea (Vasseur and

Kemp, 2015) and Nigeria (Ohunakin et al., 2014) where inaccessibility to solar PV spares and logistical problems were linked to lack of robust solar PV markets. Unlike in most developing countries, the availability of spares was rarely mentioned among developed countries, possibly because they have readily available industries which manufacture spares. For instance, countries such as China (Lo et al., 2018) and German (Gao and Zhou, 2023) have invested in solar PV manufacturing plants, making it cheap to buy and service solar PV systems. The expectation is that a wide network of solar PV technology manufacturing industries can broaden the market, making parts affordable and accessible to many households. However, there is need for South Africa and other developing countries to invest in establishing solar PV industries and developing the human skills needed for establishing the industry.

Another technical barrier to solar PV adoption reported in the reviewed studies relates to the malfunctioning of appliances Aigbavboa (2015). For instance, Aigbavboa (2015) found that households reported malfunctioning of government installed solar water heaters including leakages, which discouraged other households from accepting the technology. The study also found that the solar water heaters produced an unpleasant noise during use of hot water taps, suggesting a lack of expertise in installation and maintenance. In the absence of government solar PV specialists, households tend to rely on private operators which are highly expensive and inaccessible to low-income groups. In developed countries, after the installation and commissioning of a solar PV system, suppliers continue to support the customer during routine maintenance appointments and solar PV system troubleshooting requests at no additional cost for the duration of the system's warranty (Prajapati, 2022). This arrangement can boost adopters' confidence in using the solar PV systems as well as address technical challenges they may face after installation. Similar arrangements can increase the level of trust and chances of solar PV adoption in South Africa.

Social barriers

Social barriers reported in the reviewed literature include theft of solar PV appliances and spares (Bikam and Mulaudzi, 2006; Azimoh et al., 2014; Chidembo et al., 2022a). For instance, Bikam and Mulaudzi (2006) reported that some households in Folovhodwe village had discontinued investments in solar PV energy because of the high rate of theft in the area, including of solar PV appliances. In the Vhembe district of South Africa, Chidembo et al. (2022a) also found that though households perceived solar PV energy as environmentally friendly and cheap, they were unwilling to install solar PV systems because of fear of theft. Azimoh et al. (2014) reported that adopters of solar PV used most of their energy towards lighting to prevent crime, which in turn, reduced the capacity of the solar PV systems to support the households' primary needs such as powering appliances. The issue of insecurity of solar PV systems as a barrier to adoption has been reported elsewhere. For instance, in Papua New Guinea, households opted not to invest in solar panels to avoid inviting criminals to their houses (Sovacool et al., 2011). Similar findings were reported among British households where community concerns including security were noted as additional barriers to solar PV adoption among households (Faiers and Neame, 2006). However, improvements in solar PV technology such as security lighting in the form of floodlights connected to motion sensors and anti-theft fasteners can help reduce theft (Thompson, 2020) but in low-income areas the costs of such measures should not be expected to be borne by households. Other security related solutions include the use of advanced alarm systems that can proactively warn users about intruders. These security technologies can be mainstreamed by South Africa through information campaigns to increase solar PV uptake amongst local households. However, it is important to acknowledge that these security features may come with extra costs which might limit some households from affording them.

In most cases, barriers reported in South Africa are comparable to those reported elsewhere (Vasseur and Kemp, 2015; Jacobsson and Lauber, 2006). For instance, financial barriers have been reported among developed countries such as Sweden (Palm, 2018), Germany (Jacobsson and Lauber, 2006), and the Netherlands (Vasseur and Kemp, 2015), as noted in the analysis. However, while technical barriers are universal, they differ in nature based on geographic settings. For example, unlike South African households, which face barriers in the form of technical faults and non-availability of solar PV system maintenance, in developed countries such as the United Kingdom (UK) technical barriers relate to limited rooftop space for installing panels, rooftop suitability in terms of accessibility for maintenance, and rooftop shading caused by plant growth covering the solar panels (Patience, 2024). In many European households, rooftop plants covering solar panels are common, making some homeowners unwilling to undergo constant rooftop maintenance to eliminate these plants (Patience, 2024).

2.4. Implications and recommendations

This scoping review provides useful insights on the barriers of solar PV adoption among South African households. It shows that barriers to solar PV adoption vary ranging from personal to institutional, with such barriers likely to affect households disproportionately, with more negative effects on low-than on high-income households. For instance, the results show that adoption of solar PV systems requires a high capital investment which is beyond the reach of many South African households, especially those located in low-income areas. Approximately 55 % of the people in South Africa are classified as low-income households, and 20 % are considered middle income (Businesstech, 2023), implying that these two income groups will struggle to move towards solar PV if these barriers were not addressed. Compared to high-income households, both low- and middle-income households lack access to credit facilities, have limited roof space for installation of solar panels as well as limited knowledge and awareness which might constrain their ability to adopt solar PV systems. Moreover, because of apartheid discriminatory spatial arrangements, most low-income households are in neighbourhoods with poor security which might discourage solar PV adoption due to theft concerns. Yet, it seems like there is an urgent need for low and middle-income households to adopt solar PV given that they disproportionately incur the costs of power cuts because they cannot afford alternative energy sources such as generators. Further, most low-income households are debt ridden, with more than 60 % having unsustainable debts (Businesstech, 2023) which disqualifies them from accessing loans. Therefore, there is a need to address barriers that directly affect low- and medium-income groups for a just transition to solar PV adoption in South Africa. The current government solar PV incentives (e.g., the 25 % solar PV rebate) will only benefit the high-income households as they have the means to purchase Solar PV systems through disposable income or bank loans.

A consideration of all these factors combined might explain the reason behind the low and slow adoption of solar PV among the low-income households in the country as highlighted in the literature (Mulaudzi et al., 2022). Hence, a socially just transition to solar PV energy in South Africa might be achievable through the introduction of equitable policy frameworks which support inclusive transitions. For instance, the government should put in place inclusive financial legislations which cater for low- and middle-income households. The government can also initiate or support power purchase agreements whereby solar PV systems are installed in homes at reduced costs, and the energy generated will be sold to the homeowner at a set contractual price. Power purchase agreements can address the lack of trust and perceptions of limited capacity of solar PV systems to produce sufficient energy and at the same time minimise start-up financial costs, which could in turn, encourage solar PV adoption. Power purchase agreements have proven to be effective among low- and medium income households in California, USA (Chao, 2020). Californian households have also benefited from the government solar PV leasing exercise where the government contracts solar PV companies to lease solar panels to homeowners who pay for them over a long period of time (Liu et al., 2014; Chao, 2020). These initiatives can be very effective in South Africa, given that most low- and medium income households in South Africa are debt ridden and hence, cannot qualify for loans (Kereeditse and Mpundu, 2021). Moreover, these initiatives can also cater for the low- and medium income households who are key consumers of energy in South Africa (Kambule et al., 2018). Alternatively, the government can also create financial institutions that offer loans or financial help to household adopters at zero or low interest rate for solar PV system adoption. Similar initiatives have been successful in Ghana (Steel et al., 2016) and Kenya (Ondraczek, 2014), with solar PV adoption positively linked with various kinds of incentives and credit arrangements through the rural and community banks initiative. To reduce the financial burden of low- and middle-income households, the government can also promote adoption of solar PV by reducing import duties for solar PV products which can reduce the upfront costs of solar PV systems.

In discussing the challenges facing widespread adoption of solar PV technology, it is imperative to recognise that institutional, financial, social, and cognitive barriers are deeply interconnected and cannot be addressed in isolation. Institutional barriers such as outdated regulations or bureaucratic hurdles, often intersect with financial constraints, limiting access to necessary funding and investment. Moreover, social factors, including public perception and community acceptance, play a pivotal role in shaping the uptake of solar PV systems. Additionally, cognitive barriers, stemming from misinformation or lack of awareness, further hinder progress in this transition. Recognising and addressing these barriers holistically is essential for fostering a conducive environment for the widespread adoption of solar PV technology, unlocking its full potential in the global transition towards sustainable energy.

2.5. Research gaps and future recommendations

Although the reviewed articles provide useful insights, future research needs to focus on the comparisons between perceived and objective barriers as this can determine what solutions might be needed to address them. Perceived barriers refer to an individual’s assessment of the challenges they may face in trying to change their behaviour (Janz and Becker, 1984). In this context perceived barriers refer to households' assessment of the challenges associated with solar PV adoption. Objective barriers on the other hand refer to practical challenges encountered in solar PV adoption (Chao, 2020). Although it was not the focus of this study, most of the work reviewed in this study focused on perceived barriers. Thus, future research needs to focus on objective barriers as these show an accurate reflection of factors deterring households from adopting solar PV. As already alluded to, available literature on barriers to solar PV adoption in South Africa provide limited insight into how barriers affect different income groups. This work is very important, but insufficient to capture the structural issues that shape access to renewable energy. Moreover, there is a need for studies on the barriers of solar PV among households, focusing on both adopters and non-adopters, and across an income gradient which might provide insights on what and how barriers are experienced. This can form the basis for drafting policy interventions for equitable transitions to solar PV, particularly in contexts of high levels of inequality.

2.6. Conclusions

Despite a growing unanimous agreement on the benefits of solar PV energy, there is a very low adoption rate among South African households attributable to diverse barriers including financial, institutional, technical, personal, and social barriers. Solar PV systems are still largely expensive and beyond affordability for most households in South Africa which has serious implications for energy security and environmental targets. Addressing the barriers remains important in promoting rapid uptake of solar PV systems but should be informed by up-to-date analysis of how barriers vary by income status, and distinction between perceived and objective barriers. Further collective efforts are needed to meaningfully address the barriers. Central to promoting local solar PV energy is creating a strong strategy that is inclusive of all households including those from marginalised societies. The government also needs to invest in educating households so that they can effectively ascertain the risks and benefits of solar PV to allow agency and informed decisions.

CHAPTER 3: BARRIERS TO SOLAR PHOTOVOLTAIC (PV) ADOPTION AMONG URBAN HOUSEHOLDS IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

NOTE: *This paper has been submitted to the journal of Sustainable Energy Research and it is currently under review.*

Abstract

Solar photovoltaic (PV) provides a sustainable alternative to the commonly used fossil fuel energy from economic and environmental sustainability perspectives; however, its uptake is shaped by perceived and actual barriers. Against a backdrop of heavy dependence on coal for energy generation and very high solar generation potential, solar PV adoption remains low, contributing around 5% to South Africa's energy mix, yet systematic research of barriers over multiple sites is scarce. Using household interviews, the study investigated the barriers to solar PV adoption among urban dwellers across an income gradient in four towns located in the Eastern Cape Province of South Africa. Results from household interviews show that both high-income and low-income households were constrained by financial, institutional, personal, and social barriers, with low-income households being disproportionately affected by these barriers due to limited knowledge as well as financial and institutional support. Though both high and low-income households lacked knowledge, low-income households were disproportionally affected. Correlation analysis results showed significant positive relationships between values with an affinity towards the earth/environment and the intention to adopt solar PV. Programmes for encouraging transition to solar PV adoption should prioritise addressing these barriers, recognising that promoting equitable transitions is contingent on understanding and addressing the disproportionate impacts of barriers on different demographic groups. Inclusive financial arrangements such as power purchase agreements and solar leasing programs might encourage solar PV adoption.

Keywords: Solar PV, renewable energy, barriers, adoption, transition, urban dwellers.

3.1. Introduction

The global shift to renewable energy is gradually gaining traction, mostly driven by factors such as high energy costs (Herman et al., 2023; Milewska and Milewski, 2023), the risks associated with fossil fuels, including land and air pollution (Marchetti-Mercer, 2023) and the moral responsibility to combat global environmental problems such as climate change

(Culiberg et al., 2023; Marchetti-Mercer, 2023). For example, solar PV energy has experienced a significant growth globally, increasing over 30 times between 2010 (31 TWh) and 2021 (1000 TWh) (Shakeel et al., 2023). A key discussion point on renewable energy is the need for a just transition, where all individuals and stakeholders across the economic divide are provided with the financial and institutional support to adopt renewable energy sources (Mirzania et al., 2023). A just transition in the shift to renewable energy refers to transitioning to cleaner, more sustainable energy sources in a manner that ensures fairness and equity across factors such as income, gender, and ethnicity (Lacey-Barnacle et al., 2020; McCauley and Heffron, 2018; Jenkins et al., 2016). The just transition imperative is aimed at making sure no one is left behind and that everyone has equal access to affordable reliable energy (Pathak et al., 2022). However, the transition to renewable energy can be constrained by several barriers, and without an understanding of how barriers are perceived and experienced by different demographic groups, interventions for achieving a just transition to renewable energy might be misinformed. While there is increased research on barriers linked to renewable energy transition (Chidembo et al., 2022b; McKay and Hendricks, 2022), research on the specific types and extent of barriers across various socio-demographic groups is still scarce. Such research is important, especially in countries with high levels of inequality, such as countries from the BRICS block (Brazil, Russia, India, China, and South Africa), where energy demand is high due to increased development (Acheampong et al., 2023). Advancing our understanding of the barriers to adopting renewable energy can inform interventions for reducing the inequalities that can constrain the achievement of just renewable energy transitions. Previous studies have highlighted financial, institutional, technical, social, and cognitive barriers (Irfan et al., 2019; Qureshi et al., 2017; Shimada and Honda, 2022), yet few studies have been conducted in South Africa to interrogate these barriers across an income gradient in an urban context.

Generally, barriers are defined as obstacles that prevent one from achieving their intended action, such as solar PV adoption. For example, financial barriers are monetary factors that can constrain the accessibility of solar PV systems (Qureshi et al., 2017), such as the absence of standardised pricing benchmarks for solar PV installations, which may result in high start-up costs, as reported in Japan (Shimada and Honda, 2022), Pakistan (Irfan et al., 2019; Qureshi et al., 2017) and Germany (Victoria et al., 2021). Other financial barriers relate to the lack of credit facilities among potential solar PV adopters (Cook and Bird, 2018). Evidence shows that most low- to medium-income households in the USA did not adopt solar PV because their credit scores did not qualify them to get loans (Cook and Bird, 2018). The above-mentioned study also reported that households with high credit scores were excluded from financial arrangements supporting solar PV adoption because they had other pre-existing loan commitments such as mortgages and car loans. The non-availability of supporting funds from banks and financial services among low- to medium-income households has also been mentioned among households in the Netherlands (Kılıç and Kekezoğlu, 2022). Thus, financial barriers play a significant role in determining solar PV adoption among households.

Besides financial barriers, institutional barriers relate to policies, laws, and situations that systematically disadvantage solar PV users (Lan et al., 2020). For instance, slow adoption by households in Japan (Tanaka et al., 2017), Australia (Clark and Li, 2018) and Malaysia (Ahmad et al., 2015) was attributed to the absence of comprehensive policies and Feed in Tariffs (FIT) designed to increase investment in renewable energy systems. Low FITs can discourage households from supplying excess solar PV energy to the grid as the benefits are much lower than grid energy costs (Clark and Li, 2018). In Malaysia, Ahmad et al. (2015) found that imbalances between the price at which households sell solar PV energy to companies and the price at which these companies sell energy back to households discouraged households from adopting solar PV. Institutional barriers relating to factors that disproportionately impact specific groups of people, contributing to notable disparities in how these groups benefit from certain initiatives, have also been mentioned in the literature (Ding et al., 2023). For instance, studies conducted in the USA found that there are equity concerns related to renewable energy deployment policies, which generally marginalises Black and Asian minority groups (Ding et al., 2023). Addressing institutional barriers to energy transition can ensure that there is an equitable sharing of benefits and burdens of transitions to cleaner forms of energy between the high and low-income groups of the society (Eckersley and Fitz-Henry, 2023).

Technical barriers encompass solar PV-related technological challenges such as lack of power generating capacity by solar PV systems and limited access to technology, manufacturing industries, service parts, and human technical expertise (Lo et al., 2018; Qureshi et al., 2017). For example, research conducted in Hong Kong highlighted low energy output from solar PV systems and limited rooftop space to install solar panels as key challenges to adoption (Lo et al., 2018). Further, studies conducted in China and Sri-Lanka (D’Agostino et al., 2011) as well as Pakistan (Qureshi et al., 2017) found that most households lacked the technical expertise to use solar PV systems and were dissatisfied with the performance of the solar PV systems which worked against potential solar PV adopters. Another technical barrier to solar PV adoption is the non-availability of spares and technicians. For example, Sriwannawit (2014) found that the absence of, long distance to solar PV repair shops, non-availability of spare parts and lack of trained technicians reduced the motivation to adopt solar PV systems.

Apart from technical barriers, social barriers such as theft of solar PV appliances, particularly solar panels within a community might deter households from adopting solar PV (Ahmed et al., 2022; Raymond et al., 2022; Sovacool et al., 2011). Theft of rooftop solar panels is prevalent in less secure areas, potentially resulting in extra costs to install robust security measures. A study in Guinea found that households were not willing to adopt solar PV because they attracted criminals to their homes (Sovacool et al., 2011). Similarly, theft and vandalism of solar panels were reported in Tanzania, which in turn, deterred people from installing solar PV, especially where no legal action is taken against suspected perpetrators of these crimes (Raymond et al., 2022). A study comparing solar PV adoption in Pakistan and Somalia also identified security concerns regarding solar PV theft as a key social barrier that hindered adoption (Ahmed et al., 2022).

Beyond external factors, factors such as cognitive influences and values can influence people's decisions to adopt solar PV. Cognitive factors are characteristics within a person that affect their ability to learn or behave (Podder et al., 2021), and can play a pivotal role on households' decision-making process (Etongo and Naidu, 2022; Wang et al., 2023). For example, lack of knowledge on solar PV systems, including how they function is one of the most significant cognitive barriers to solar PV adoption (Etongo and Naidu, 2022; Wang et al., 2023). For instance, studies conducted in Seychelles (Etongo and Naidu, 2022) and Bangladesh (Podder et al., 2021) have shown that insufficient information among adopters contributes to ineffective utilisation and maintenance of solar PV systems, consequently shortening their lifespan. These negative experiences attributed to lack of knowledge can contribute to negative perceptions of solar PV systems, which in turn, could discourage potential solar PV adopters. Earlier studies on the transition to renewable energy emphasised the importance of providing tailored information and education to facilitate the successful implementation of new technologies (Etongo and Naidu, 2022; Sriwannawit, 2014).

The motivation to adopt solar PV can also be influenced by one's values and motives. Values are defined as "important life goals or standards that serve as guiding principles in life" (Poortinga et al., 2004)(p. 71). Value orientations can broadly be categorised into two dimensions. The first dimension of values differentiates between openness to change (e.g., self-direction and stimulation) and conservatism (e.g., conformity and traditionalism). The second dimension differentiates self-enhancement values (e.g., values factors aligned to power and security) and self-transcendent values (e.g., altruistic orientations such as benevolence and universalism) (Schwartz, 1994). Broadly speaking, individuals with an affinity towards conservative values are less likely to make choices that favour the environment because they are less receptive to new ideas and prefer conventional routines than those with self-transcendent value orientations (de Groot and Steg, 2007). Drawing on this, it can be argued that people with a conservative value orientation are less likely to adopt solar PV, driven by their inclination to maintain routines and their desire for immediate gains. On the other hand, it can also be argued that people who consider self-transcendent values as very important are more likely to be receptive to solar PV adoption than those who do not. Given the above, further research is needed to understand the role of people's value orientations in predicting environmentally friendly actions such as solar PV adoption. This is because decisions can be driven by either egotistic or altruistic motivations, which can either encourage or discourage households from adopting solar PV.

3.1.1. The South African context

The above-mentioned barriers have hardly been interrogated in South Africa, yet the country's current energy challenges have pushed the government to prioritise and fast-track the adoption of renewable energy, including solar PV. Besides, South Africa is one of the biggest emitters of carbon dioxide in the world and is under intense pressure to minimise its energy-related carbon emissions (Calitz and Wright, 2021), hence solar PV adoption is urgently needed. In addition, the country's main energy distribution company (Eskom) is going through a financial crisis, limiting its operations, and has resorted to power cuts and tariff increases to remain afloat (Eskom, 2020, 2023). These challenges at Eskom have resulted in the government channelling its effort towards renewable energy sources to increase energy supply (Calitz and Wright, 2021). To increase the uptake of solar PV, the South African government offered tax rebates of up to 25% of the total cost of the solar panels for all installations done as of March 2023 (South African National Treasury, 2023). Further, South Africa has a lot of sunlight since the country receives about 2500 hours of sunlight per year, which is estimated to be around 6 kWh/m^2 per day (IRENA, 2022). However, despite the potential of solar PV systems to provide an alternative energy source in South Africa, the rate of adoption is still very low due to multi-dimensional challenges (McKay and Hendricks, 2022; Chidembo et al., 2022b). Projections in

South Africa indicate a slow growth of solar PV adoption that cannot meet the current energy demand, which requires an interrogation of the barriers to adoption (IRENA, 2022). Current estimates suggest that solar PV contributes less than 5% to the country's energy mix and has been adopted by only 10% of households (IRENA, 2022). Hence, the identification and analysis of barriers from a local perspective can help in crafting solutions for promoting the rapid uptake of solar PV systems in South Africa.

South Africa's household sector is highly differentiated by income, with stark contrasts between high and low-income residential areas (Statistics South Africa, 2022). Therefore, to understand barriers to solar PV adoption in South Africa, studies should be conducted across a socio-economic gradient if meaningful interventions that support a just transition to solar PV are to be developed. Given this background, this study aims to evaluate the barriers households face in adopting solar PV systems in South Africa. Key research questions for the study were: (i) what are the key barriers to solar PV adoption? (ii) how do these barriers vary between income groups?

3.2. Methods

3.2.1. Study areas

The study was conducted in four urban areas located in the Eastern Cape province of South Africa (Figure 3.1). The province's abundant sunlight makes it an ideal location for solar PV adoption. Two of the selected urban areas are cities, namely, Gqeberha (formerly Port Elizabeth) and East London, which are classified as metropolitans because of their exclusive and legislative authority, whereas the other two, Makhanda and Komani (formerly Grahamstown and Queenstown, respectively), are classified as big towns since their population exceeds 20 000 people. Gqeberha, which is in the Nelson Mandela metropolitan municipality, is in a convergence vegetation area where fynbos, grassland, thicket, and forest biomes intersect (Mucina and Rutherford, 2006). The area receives both winter and summer rainfall and has an oceanic climate due to its proximity to the ocean. It has a population of 1,280,550 people and a population density of 2,572 per square kilometre (Statistics South Africa, 2022). East London is part of the Buffalo City metropolitan municipality, and it is situated in Albany thicket biome, which is characterised by shrubs and herb-like wildflowers (Mucina and Rutherford, 2006). East London has a population of 403,581 and a population density of approximately 1,720 people per square kilometre (Statistics South Africa, 2022). Makhanda is situated in the Albany thicket biome (Mucina and Rutherford, 2006). It has a population of about 75 170 and a population density of about 1 034 per square kilometre, with an annual population increase of about 0.86% (Statistics South Africa, 2022). Komani is a big town situated in the grassland biome (Mucina and Rutherford, 2006), and has a population of about 122 365 people and a population density of about 957.4 per square kilometre with an annual increase of about 1.6% (Statistics South Africa, 2022). Overall, the Eastern Cape province is one of the poorest provinces in South Africa, characterised by low literacy levels of 20.5% and a high unemployment rate of about 42% (Statistics South Africa, 2022). Approximately 40% of the Eastern Cape's population benefits from the government's social grants scheme (Statistics South Africa, 2022), illustrative of high poverty levels. Moreover, the province reports the highest number (21.7%) of free basic electricity units given to households (Mukumba and Chivanga, 2023), indicating a high level of energy poverty, though poor households are disproportionately energy-poor. Free basic electricity refers to the 50 kWh provided to poor households by the government to curb the adverse impacts of energy poverty (Eskom, 2023). Consistent with most South African urban areas, the selected study towns have high spatial segregation, which dates back to the segregation policies of the apartheid government, which aimed to separate human settlements based on race (Strauss, 2019). High-income suburbs are characterised by large houses, good educational facilities and social services, while low-income households are characterised by small houses built on small pieces of land. In addition, most low-income suburbs in South Africa have Reconstruction and Development Programme (RDP) houses that were built by the government post the democratic transition in 1994 to provide houses to the poor. Low-income areas are typically characterised by high levels of illiteracy and poor service delivery (Statistics South Africa, 2022). To address the adverse effects of energy poverty amongst poor households in low-income suburbs, the South African government introduced solar water heaters to some low-income households under the South African solar water heater (SWH) programme (Department of Energy SA, 2019).

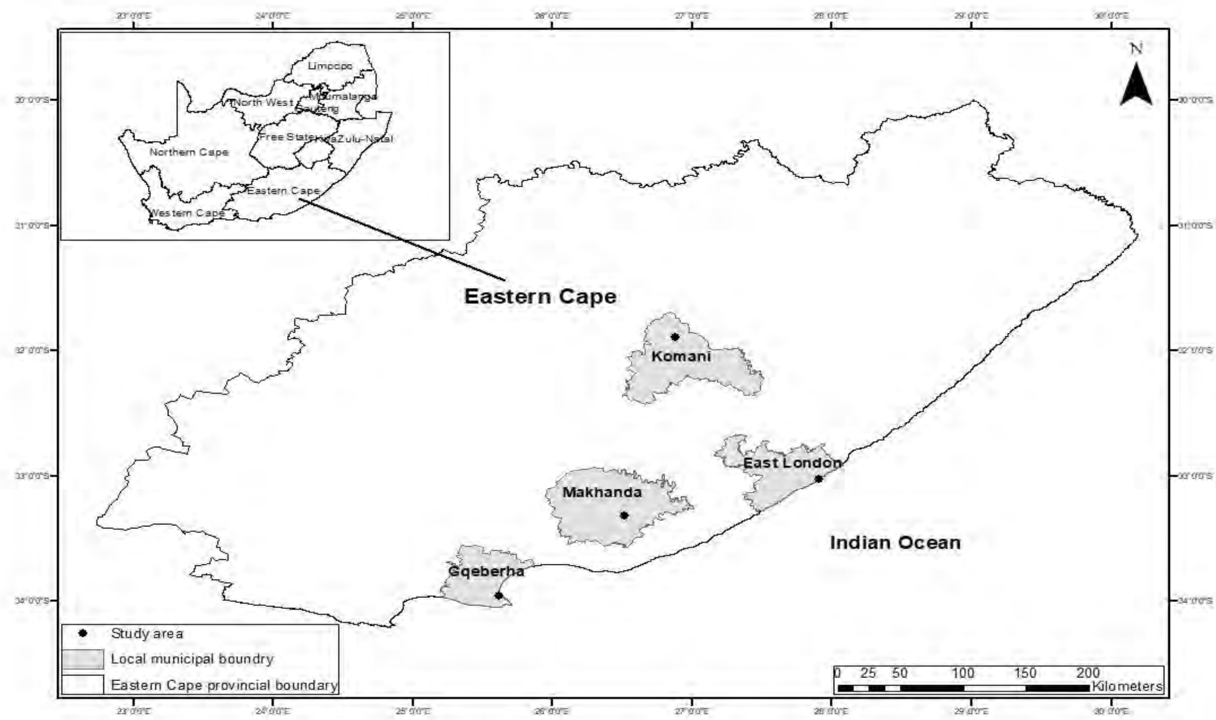

Figure 3.1. Location of the four study cities and towns in Eastern Cape Province of South Africa.

3.2.2. Sample design

Data collection for this study was carried out between November 2022 and February 2023 in the four cities and towns. The cities and towns were purposively selected based on their population size and location, and in this case, two metropolitans and big towns that are located along the coast and inland. The justification for the selection criterion was to gather a wide range of solar PV adoption views across different urban areas that are in different environmental conditions. Within each of the four selected urban areas, non-solar PV adopters were selected across high- and low-income suburbs. The distinction between high- and low-income households was determined by the location of the households. Justification for selecting non-adopters of solar PV adoption was to get insights into barriers to solar PV adoption. One income group suburb was randomly selected per study area, and randomisation was achieved by (i) identifying, using Google Earth, and listing all the suburbs in the urban area, (ii) assigning numbers to all the identified suburbs, and (iii) using the excel RANDBETWEEN function to select one sampling suburb per income group and per urban area. After selecting suburbs, a random selection of households to be interviewed was conducted. To achieve that sampling, streets were selected randomly using the above-described random selection procedure. Once the streets were selected, the researchers targeted the first house on the street, thereafter, a systematic sampling selection was adopted where every fifth household was interviewed. In cases where respondents from the selected household were not available or not willing to participate, the next available household was selected. The interviews targeted household heads, and in the absence of the household head, the eldest member of the household present. The questionnaires targeted 20 high-income and 20 low-income households in each study urban area (160 households in total), thus offering a big sample size that allows comparison and statistical rigor. However, due to security concerns, especially among the high-income households, it was difficult to access some households, and 143 households across the study towns participated in the study. Prior to conducting the study, ethics approval was secured through the Rhodes University Ethics Committee (Review reference number 2022-5895-7199).

3.2.3. Data collection

The selected households from the four study towns were interviewed via household questionnaire surveys. The questionnaires were administered in the preferred language of the respondents, either English or IsiXhosa, with the help of a translator for the latter. The interview questionnaires were pre-tested to identify any issues related to length, relevance, and clarity of questions to respondents. The questionnaire was divided into four sections covering key themes of the study. The first section gathered information on the respondents' perceptions of solar PV adoption, including the intention to adopt solar PV and perceived benefits and risks. Intentions to adopt solar PV were assessed by asking households questions such as *"Have you ever considered adopting solar PV energy for your home, and if so, give reasons?"* with responses ranging from either Yes or No followed by a reason for the given response. To evaluate the risks and benefits of adopting solar PV, households were asked to indicate their agreement with various predetermined statements, such as: *"I would worry about having solar energy because it would be expensive to maintain"* and *"Solar energy helps slow down climate change"* using a scale ranging from "Strongly agree" to "Strongly disagree".

The second section collected information on financial, technical, institutional, and cognitive barriers to solar PV adoption. Information on financial barriers was collected by asking respondents to indicate their agreement with various predetermined statements, such as: "*I would worry about having solar PV energy because they would be expensive to maintain.*" Similarly, information on technical barriers was collected by asking respondents to indicate their level of agreement with questions such as: *"I would worry about having solar energy* *because I do not have rooftop space to install it"*. To collect information on institutional barriers, respondents were asked questions such as: *"Do you feel that the government (favourable policy instruments) might support your decision to purchase solar for your household?"* with responses ranging from choosing either Yes or No followed by a reason for the given response. Solar PV knowledge was classified into three distinct groups: "knowledgeable," "partially knowledgeable," and "not knowledgeable," following Ali et al. (2023). Respondents were considered knowledgeable if they demonstrated a comprehensive understanding of the technical processes involved in solar PV energy generation, including storage, demand, and availability dynamics. Individuals falling under the "partially knowledgeable" category displayed limited knowledge of how solar PV systems work. For instance, they may be aware that solar PV systems convert energy from the sun but lack an understanding of the technical processes integral to their operation. Those categorised under "not knowledgeable" completely had no idea of how solar PV systems function.

The third section captured the respondents' value orientations. Respondents were requested to rank the level of significance they attributed to a set of personal value orientations (22 Quality of Life factors) following Schwartz (1994), using a five-point Likert scale (ranging from 1 = unimportant to 5 = critical). Individual scores within each domain were aggregated, with average scores nearing 1 and 5, indicating a low and high disposition towards the specific value orientation, respectively. The fourth section collected respondents' profiles, including age, gender, education level, income, home language, and household size. See Appendix 3.1 for the survey instrument.

3.2.4. Data analyses

Data were analysed using descriptive and inferential statistics. Statistica version 14.0 (TIBCO Software Inc, 2019) was used for all inferential statistics. Tables and proportions were used to summarise the socio-demographic data. Numeric demographic data such as mean household size and average age of respondents were analysed using a T-test to compare differences between high and low-income households. Interview responses were transcribed and analysed through thematic analysis to extract key insights. The themes were created following a method suggested by Braun and Clarke (2006). The first stage involved data capturing and familiarisation and the generation of initial codes. This was followed by an organisation of identified codes into potential themes. The following stage involved reviewing and refining potential themes, eliminating those lacking supporting data and breaking down overly broad ones. The final stage involved naming and defining the themes to capture their essence. A Spearman's correlation analysis was performed to explore the relationship between values and the intention to adopt solar PV.

3.3. Results and discussion

3.3.1. The socio-demographic profile of respondents

Across all study towns, the number of male (51%) and female (49%) respondents was evenly distributed in the high-income area compared to the low-income area, which had more female (64%) respondents (Table 3.1). The uneven distribution by gender in low-income households could be because females in the sampled urban areas are generally unemployed, self-employed, or working from home (Statistics South Africa, 2022). The mean household size for high-income households (3.4±1.5) was significantly lower than that of low-income households (5±2.6) ($t = 3.811$; $p = 0.001$). Across all sampled study towns, the average age of respondents was significantly higher for high-income households (52±15) than low-income households (46±14; $t = 2.138$; $p = 0.034$). Among the high-income households, the level of education was generally high, with the majority (88%) having attained tertiary-level education. In contrast, most of the low-income households (74%) had only secondary-level education. Just above half (51%) of the high-income households were formally employed, reporting a monthly income of more than ZAR30 000.00 (US$1565.67), while most of the low-income households (67%) were dependent on government's social grants (Table 3.1). Social grants are given to low-income households to reduce poverty as part of government's broader social welfare mechanisms (Statistics South Africa, 2022). Among the few low-income respondents who were formally employed, most of them received a monthly income of less than ZAR6 000.00 (US$313.14), indicative of low-income status. About two-thirds (66%) of the respondents across all income groups had stayed in the study areas for more than 20 years.

Table 3.1. The socio-demographic profile of the respondents

Attribute	High-income (n=49) (%)	Low-income (n=94) (%)	All (n=143) (%)
Gender of respondents (%)			
Female	51	64	58
Male	49	36	42
Level of education (%)			
Primary	-	11	5.5
Secondary	12	74	83

Tertiary	88	3	45
Household income source			
Own business	39	7	22
Private pensions	8	-	4
Social grants	2	67	61
Wages	51	26	48
Household monthly income (ZAR)			
<2000	2	44	41
2 001-6 000	-	44	41
6 001-15000	13	8	12
15 001-30 000	28	4	12
>30 000	57	-	23
Length of stay			
0-10 years	12	1	7
11-20 years	30	30	30
21-30 years	28.5	19	23
31-40 years	2	18	20
>40 years	26.5	32	29

3.3.2. Respondents' perceptions of solar PV energy

The respondents were asked if and why they had considered solar PV adoption in the past years. More than half of the respondents in both income groups reported that they had considered solar PV adoption, but significantly more high-income (82%) than low-income (63%) households reported so (χ^2= 15.359, p= 0.004). When respondents were asked when they began seriously considering adopting solar PV, similar trends were found with significantly more high-income (76%) than low-income (50%) households reporting the past 2 years (2021-2023) (χ^2= 6.614, p = 0.010). This period coincides with high levels of power outages in South Africa. For example, the country experienced 72.6 days of power outages in 2023 alone, which is double the 2022 levels (Businesstech, 2024a). The main reason for solar PV consideration reported by 89 % of all households was to find an alternative energy source to deal with persistent power cuts. Elsewhere, the need for grid independence and power outage concerns were also found to be the reason why most households in Seychelles and Pakistan were considering adopting solar PV (Etongo and Naidu, 2022; Qureshi et al., 2017). When asked about the perceived benefits of solar PV adoption, nearly all respondents acknowledged its potential to alleviate power outages (Table 3.2). A significant number of respondents from both income groups in all the study towns acknowledged the benefits of adopting solar PV such as reducing power cuts. However, perceptions of these benefits varied. For example, about 8% of high-income households viewed alternatives like diesel generators and storage batteries as more cost-effective than solar PV systems, consistent with findings by Bakri et al. (2022) among Nigerian households. In contrast, most low-income households considered solar PV to be cheaper because they believed it was provided by the government. Moreover, a majority of both high-income (64%) and low-income (89%) households stated that solar PV provided a cost-effective alternative to grid energy provided by Eskom, but at least 20% more low-income households reported so (χ^2= 14.215, p= 0.003). This suggests that the cost-saving potential of solar PV systems is more appealing to low-income households, possibly because of their limited financial resources. In South Africa, low-income households struggle with high energy bills (Mutumbi et al., 2022), and thus, the idea of reducing this burden through solar PV systems is attractive. A substantial proportion of both high-income (79%) and low-income (82%) households either agreed or strongly agreed that solar PV could help slow down climate change, which reflects a widespread awareness about the environmental benefits of renewable energy sources irrespective of income levels. The environmental benefits of solar PV systems have also been reported by Irfan et al. (2019) among Dutch neighbourhoods and Culiberg et al. (2023) among British households, who found that the decision to adopt clean sources of energy was determined by the desire to reduce greenhouse gas emissions. However, our study suggests that the main driver for solar PV adoption was the need for a reliable source of energy rather than sustainability factors such as environmental concern.

Table 3.2. Consideration and perceived benefits of solar PV adoption.

Attribute	**High-income (n=49) (%)**	**Low-income (n=94) (%)**	**All (n=143) (%)**	**Chi-Square (X^2)**	**p-values**
Consideration of adoption					
Yes	82	63	72.5	15.359	0.004*
No	18	37	27.5		
Period since consideration					
In the past 2 years	24	50	37	6.614	0.010*
More than 2 years ago	76	50	63		
Solar PV curbs power outages					
Yes	96	100	98	4.153	0.245
No	4	-	2		
Solar is a cheaper alternative					
Yes	64	89	71	14.215	0.003*
No	20	5	15		
Not sure	16	6	14		

3.3.3. Reported barriers to solar PV system adoption

Financial barriers

When asked about reasons for non-adoption of solar PV, more of high-income (86%) than low-income households (58%) cited financial constraints (χ^2= 27.519, p= 0.001). This can be attributed to the fact that high-income households generally perceive the capital investment of solar PV as more expensive when compared to other alternatives, they have access to, such as diesel generators or storage batteries. They might find these alternatives more immediately cost-effective or reliable compared to solar PV systems, as literature suggests that diesel generators offer immediate power solutions than solar PV systems, which require a high initial investment (Jude, 2023). At the same time low-income households might perceive solar PV as a more affordable option, especially if there are government donations involved (Department of Energy SA, 2019). It is important to note that similar perceptions of financial barriers do not translate to similar meanings between different demographic groups. Thus, addressing financial barriers requires understanding the nuances of these and tailored interventions informed by contextual realities. When households were further asked about their level of agreement with statements on financial barriers to solar PV adoption, nearly two times more low-income households (48%) than high-income households (26%) (Figure 3.2) perceived solar PV system maintenance costs to be excessively high (χ^2= 26.031, p= 0.001). The findings suggest that the transition to solar PV among South African households may be constrained by the perceived high prohibitive costs that are affordable to a limited number of well-off households. The results suggest that affordability concerns persist among both high and low-income households. Thus, achieving a just transition to solar PV adoption in South Africa and beyond requires the provision of more opportunities, such as subsidies and loans for financially needy households. Affordability concerns on the adoption of solar PV have been reported elsewhere. For instance, Qureshi et al. (2017) found that high start-up costs were one of the main barriers to the diffusion of solar PV among households in Pakistan, especially in the absence of supportive financial arrangements by the government. Etongo and Naidu (2022) similarly found that solar PV requires significant capital investment, making it unaffordable for most low-income households without subsidies or government assistance.

Thus, calls for a just and inclusive energy transition require inclusive policies and programmes that support people's propensity to purchase and maintain solar PV systems. These policies can be in the form of inclusive financial legislation to support households, especially low-income households. For example, power purchase agreements can enable the government to install solar PV systems in households and sell electricity to homeowners at a fixed pre-set price, thus, reducing upfront costs (Chao, 2020; Liu et al., 2014). Power purchase agreements have been implemented with success among low- and medium-income households in California, USA (Chao, 2020). In California, households have benefited from the government's solar PV leasing program, where solar PV companies are contracted to lease panels to homeowners who then pay for them over time (Chao, 2020; Liu et al., 2014). Although power purchase agreements have been successful in other countries, their success in South Africa might be constrained by the government's interest in 'cheap' coal-powered energy, making solar PV power more expensive to buy than grid energy. For example, a study conducted in Stellenbosch, South Africa, found that the local municipality would lose up to 2.4% of its annual revenue if all households transitioned to solar PV (Korsten et al., 2017). Thus, the limited effort from the South African government, Eskom, or municipalities to promote solar PV adoption can be attributed to the potential revenue loss from reducing dependence on conventional energy sales.

Technical barriers

Concerning technical barriers to solar PV adoption, a nearly similar proportion of high-income (31%) and low-income (33%) (χ2= 26.572, p= 0.001) households expressed concerns about the weather dependency of solar PV systems (Figure 3.2), stating solar PV systems were unreliable during dusty and wet weather conditions. Concerns relating to the reliability of solar PV systems have also been reported by Azimoh et al. (2015), where it was reported that some rural households in South Africa shunned the government-donated solar PV systems due to fear of being pseudo-connected to an unreliable weather-dependent energy source which could prevent them from accessing grid energy. Apart from weather-related concerns, limited rooftop space was also reported by nearly 20% of all households but nearly two times more high-income households (24%) than low-income households (14%) reported so (χ^2= 37.744, p= 0.001). The weather-related concerns reported are against a backdrop of empirical evidence that shows South African weather conditions are quite favourable for solar PV usage, receiving an average of 6 kWh/m^2 per day (IRENA, 2022). Further, the country experiences minimal chances of harsh weather conditions like hailstorms, which might damage the panels (Mahlobo et al., 2019). Therefore, with the right systems and enough storage of solar PV energy, households should be able to sustain most of their energy needs even during rare adverse weather conditions. Concerning limited space, stakeholders such as government, solar PV installers and designers need to promote several methods of solar PV installations for households with limited rooftop space. Such methods may include balcony or carbon-steel ground-mounded solar PV systems to minimise chances of theft, as seen elsewhere (Yao and Zhou, 2023). It has also been found that the installation of monocrystalline solar panels, which are 20% more powerful than traditional polycrystalline solar panels, can reduce the number of solar panels needed, which, in turn, addresses space limitations (Jude, 2023). However, these are more expensive, and the manufacturing process of monocrystalline panels produces a substantial amount of silicon waste (Jude, 2023), which is likely to counter the environmental benefits of solar PV installation. Alternatively, the government, local municipalities, and other stakeholders could explore the feasibility of communal solar PV projects, where solar PV systems are installed on large community spaces where energy is distributed through mini-grids. This approach can address individual concerns regarding space and aesthetics. Moreover, community solar PV initiatives are likely to be cheaper as the financial burden of installation and maintenance of the systems is shared by community members (Maghami et al., 2023). In addition, community solar PV systems are easier to secure and protect from theft than individual/ private systems as resources, security infrastructure and personnel are committed to few communal points.

Social barriers

When respondents were asked about the security of solar PV panels, more than half of all respondents were worried about theft of solar panels, but slightly more high-income (60%) than low-income (52%) reported so (Figure 3.2). This could be because most high-income households have access to crime rate information, which might heighten their awareness of theft (Silva and Guedes, 2023). Moreover, most high-income households are isolated from each other, which makes them easy targets for crime (Statistics South Africa, 2018). Though more high-income households expressed concerns regarding theft of solar PV systems, results indicate that theft is a widespread barrier affecting both high-income and low-income groups, as reported elsewhere (Chidembo et al., 2022a; Sovacool et al., 2011). For instance, Chidembo et al. (2022a) found that households in the Vhembe district in Limpopo province, South Africa, were less willing to adopt solar PV because of high crime rate. Similarly, a study conducted in Papua New Guinea found that residents preferred to invest in less exposed projects that did not invite crime rather than investing in solar PV systems (Sovacool et al., 2011). However, theft seems more prevalent in less developed countries than in developed countries since solar PV distributors in some developed nations distribute solar PV systems with anti-theft fasteners in addition to security lighting, such as motion-sensor-connected floodlights (Thompson, 2020). Using sophisticated alarm systems to proactively alert people to attackers is one of the other options, especially considering the high crime rate in South Africa urban areas. While installing security measures on solar PV systems could be an option, it can be constrained by high costs, particularly for individuals who are already struggling to afford solar PV systems in the first place. Thus, the government can subsidise security features on solar PV systems so that they do not come at an extra cost. The government can also partner with existing security companies to offer discounted monitoring services for solar PV systems. These security arrangements can create a safe environment that can foster adoption.

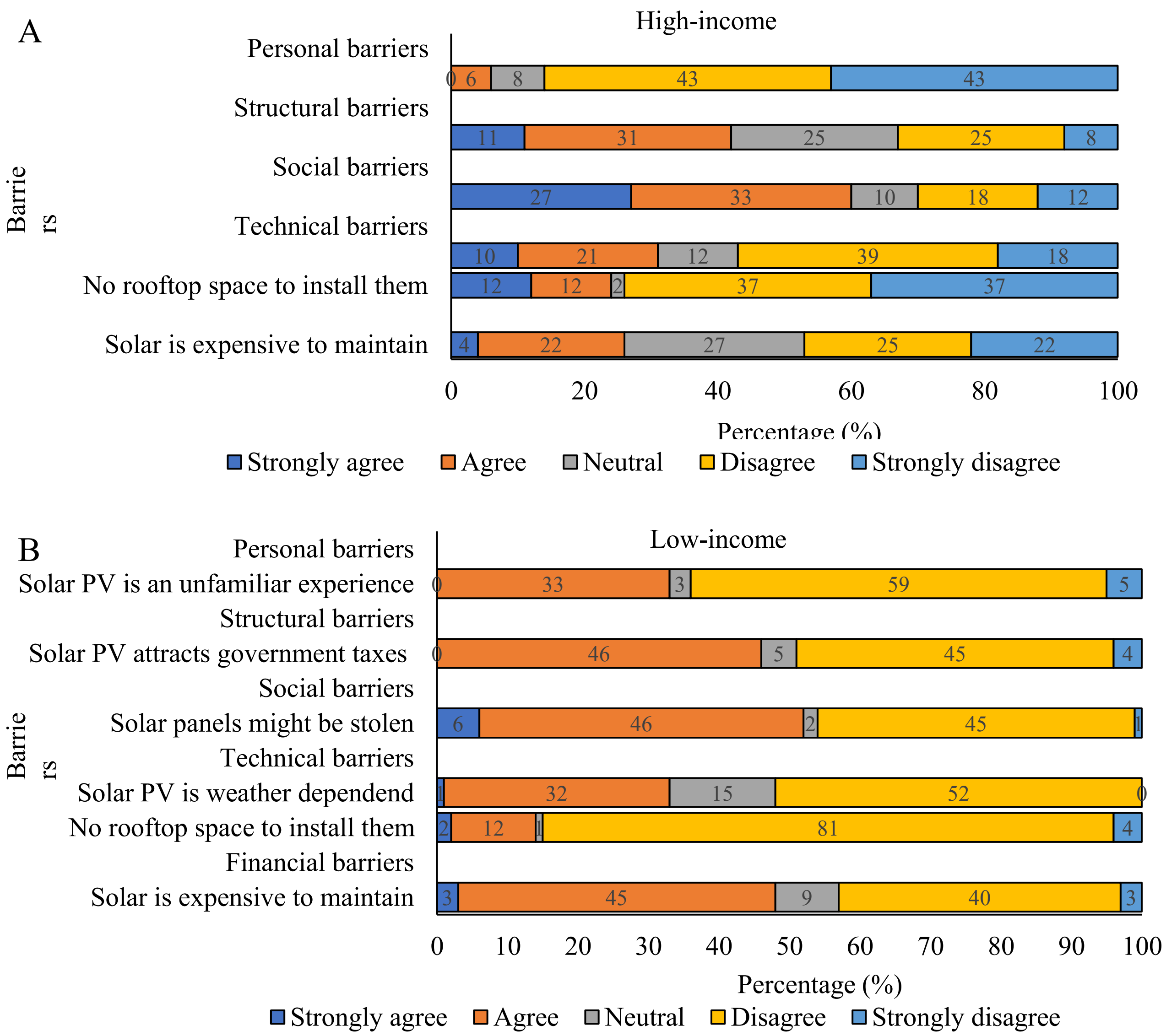

Figure 3.2. Reported barriers to solar PV adoption in a study conducted in Eastern Cape Province of South Africa

Institutional barriers

Regarding institutional barriers, significantly more high-income (42%) than low-income households (35%) (χ^2= 37.036, p= 0.001) felt that the government had no comprehensive and supportive solar PV adoption policies (Table 3.3). Similarly, when households were asked about the perceived level of ease in supplying excess electricity to the national grid, significantly more high-income households (48%) than of low-income households (33%) perceived it as either difficult or very difficult ($\chi^{2=}$ 15.359, p= 0.004).

Broadly, these results show that income status influences perceptions of barriers to solar PV adoption. Institutional barriers relating to the lack of supportive solar PV policies were reported by relatively few low-income households possibly because they have previously benefited from government solar geyser programs (Department of Energy SA, 2019). For instance, as a way of mitigating the adverse impacts of energy poverty and diversifying the country's energy mix, the government, through the Solar Water Heating program, has distributed solar water heaters to selected low-income households in different provinces in the country (Department of Energy SA, 2019). Thus, most low-income households, with the knowledge of government-led solar PV initiatives, could have presumed that the government has policies that support solar PV. Contrary to that, literature suggests that the SWH programme failed because there were no grounded policies guiding the dissemination of the systems leading to thievery and corruption, with the government unable to account for the number of beneficiaries (Netshiozwi, 2019). Another example of a policy flaw that can be misconstrued as support from the government is the solar rebate programme, which started in March 2023. Although some households, especially among the high-income, have benefited from a 25% tax rebate of the total solar panel cost, this programme overlooked the most expensive components of the solar PV systems, which are batteries and inverters (South African National Treasury, 2023). Moreover, though the 25% solar rebate is important, there is uncertainty on the part of the government to continue with the programme, thus hindering solar PV adoption (Businesstech, 2024b). In South Africa, feeding back to the grid is quite expensive and requires substantial upgrades, with bi-directional meters that allow the transfer of excess energy to the grid costing more than ZAR12 000.00 (US$625) (News24, 2023). Moreover, households are taxed for feeding back to the grid, yet the feed-in rate is as low as ZAR0.79/kWh as approved by the National Energy Regulator of South Africa (Githahu, 2023). Our results on feed-in tariff concerns are consistent with findings by Ahmad et al. (2015), who reported that the reason for slow solar PV adoption among

Malaysian households was due to the lack of comprehensive and financially attractive feed-in tariffs. Similarly, Lan et al. (2020) found that the installation of solar PV was strongly correlated with changes in the feed-in tariff policies in Queensland, Australia.

Households were asked if they agreed that institutional factors constrained solar PV adoption. Results showed that 42% of high-income and 51% of low-income households agreed (Figure 3.2), particularly with the notion that the government would tax them for solar PV installation. This implies that the uncertainty that comes with incomprehensive policies can negatively affect households irrespective of their economic status. Such uncertainties can discourage households' investment in renewable energy initiatives. Thus, concerns affecting both high and low-income households need to be considered when developing renewable energy policies underlain by the just transition imperative to solar PV adoption. The concept of a just transition emphasises the importance of including diverse perspectives in crafting policies and solving problems (Pathak et al., 2022).

Table 3.3. Perceived institutional barriers to solar PV adoption.

Attribute	**High-income (n=49) (%)**	**Low-income (n=94) (%)**	**All (n=143) (%)**	**Chi-square (X^2)**	***p-value***
Availability of supportive policies					
Yes	52	63	57	37.036	<0.001*
No	42	35	39		
Not sure	6	2	4		
Supplying to the national grid					
Very easy	2	2	3		
Easy	8	21	24	15.359	0.004*
Not sure	42	44	61		
Difficult	24	29	39		
Very difficult	24	4	16		

Cognitive barriers

Respondents were asked about their knowledge of solar PV systems, and only 10% of the high-income households, compared to none in the low-income areas, had knowledge of solar PV (Table 3.4). Most high-income households (63%) reported that they only had basic knowledge, while a quarter (27%) had no knowledge of solar PV systems at all. Similar results were exhibited among low-income households, where about 59% had only basic knowledge of solar PV, while the remainder (41%) did not have any knowledge at all (Table 3.4). Overall, there were significant differences between high and low-income households in terms of their knowledge levels (χ^2= 9.553, p = 0.008). When asked about the source of their knowledge, approximately 48% of high-income households reported obtaining their knowledge from advertisements and internet sources, while 26% received their information from solar PV installers and another 26% from friends and neighbours. In comparison, only 22% of the low-income households got their knowledge from internet sources and TV advertisements (Table 3.4). Instead, a substantial proportion of the low-income households reported that they acquired their knowledge from friends, relatives, and neighbours. Results also indicated significant (χ^2= 41.819, p = 0.001) differences between high and low-income households pertaining to their sources of knowledge. These results show that there is a lack of sufficient information on solar PV systems in both high and low-income households, though high-income households tended to have higher levels of solar PV knowledge than low-income households. While most high-income households rely on information from TV adverts and internet readings, most low-income rely on informal sources of information such as friends, relatives, and neighbours, reflective of the differences in access to formal and reliable information between the two groups. The way information is disseminated influences solar PV adoption. For instance, Wolske et al. (2017) revealed that solar PV adopters in the United States lacked trust on publicly available information as they viewed it as unreliable. In a similar study among households in the US, Wolske et al. (2017) identified sources such as the government and non-governmental organisations (NGOs) as the most trusted sources of information by households. Hence developing strategies to disseminate knowledge on solar PV to marginalised communities might provide the necessary information needed to understand how solar PV systems work and encourage adoption. This can come in the form of community workshops, where solar PV information is disseminated in ways that are understood by everyone, or community engagement initiatives, where communities get a platform to share knowledge or learn from the experiences of others.

The results also indicate that significantly more high-income households (51%) than low-income respondents (20%) had knowledge about storage of solar PV energy (χ^2= 14.351, p = 0.002) (Table 3.4). Similar trends were found for knowledge levels regarding power generating capacity needed to meet their household needs of solar PV systems, with nearly all low-income households (98%) a lack of knowledge compared to 60% among high-income households (χ^2=

37.036, $p = 0.001$) (Table 3.4). Additionally, households were surveyed about their familiarity with solar PV functions. Nearly three times more low-income households (36%) than high-income households (14%) expressed concerns about installing solar PV due to unfamiliarity with the system (Figure 3.2). These results underscore the importance of educating households with limited access to information on the technical factors, such as storage of solar PV energy and the general functionality of solar PV systems. Technicians typically provide accurate information on the technical requirements and energy capacity of specific solar PV systems. However, most low-income households rely on relatives, friends, and neighbours as their primary sources of information, which may not always be accurate. Thus, low-income households tend to face significant barriers to solar PV adoption due to limited access to reliable technical information from technicians, hindering their understanding of technical requirements, storage, and energy generation capacity of specific systems. In South Africa, where solar PV initiatives are relatively new, the unavailability of adequate information on solar PV systems hinders widespread adoption (Chidembo et al., 2022a; Curry et al., 2017). Limited awareness on the benefits of solar PV and the misconceptions surrounding its reliability and affordability can erode the trust households might have for solar PV. For instance, a study conducted in Nigeria found that some people felt that solar PV cannot support some household energy needs, such as powering the water pumps and cooking (Peter, 2023). Thus, encouraging households to embrace solar PV systems requires the provision of the necessary knowledge about its benefits and risks as a basis for making informed decisions. Taken together, the presence of several barriers mentioned implies that addressing a single barrier will not encourage adoption.

Table 3.4. Households' knowledge of solar PV systems.

Attribute	**High-income (n=49) (%)**	**Low-income (n=94) (%)**	**All (n=143) (%)**	**Chi-square (X^2)**	***p-value***
Knowledge of solar PV					
Knowledgeable	10	-	5	9.553	0.008*
Partially knowledgeable	63	59	61		
Not knowledgeable	27	41	34		
Source of knowledge					
Internet/ TV adverts	48	22	35	41.819	<0.001*
Installer/suppliers	26	-	13		
Friends/neighbours	26	78	52		

Knowledge of solar PV energy storage					
Yes	51	20	35.5	14.351	0.002*
No	49	80	64.5		
Knowledge of solar PV capacity					
Yes	40	2	21	37.036	<0.001*
No	60	98	79		

*denotes significant relationship

3.3.4. Influence of values on households' intention to adopt solar PV.

A Spearman's correlation analysis was performed to determine the relationship between people's value orientations and the intention to adopt solar PV systems (Table 3.5). The results show that self-transcendent value orientations such as preventing pollution of land, air or water and unity with nature (fitting into nature) yielded a significant and positive relationship with the intention to adopt solar PV systems. These results are consistent with findings by Pagliuca et al. (2022) who found positive correlations between people who care for the environment (self-transcendent values) and perceptions of solar PV adoption as important. Similarly, Mutumbi et al. (2021) found positive correlations between orientations towards pro-environmental behaviour and self-transcendent value factors such as respecting the earth. This implies that people who hold self-transcendent values are likely to be particular about the consequences of human behaviour on the environment and, by extension, have a high intention to adopt solar PV. Although most value factors did not yield a significant relationship, their influence on people's choices cannot be downplayed. Values influence behaviour only when they are relevant to the situation and hold significance for the individual involved (Schwartz, 1994). Thus, it is noteworthy to note that the impact of values tends to diminish when convenience is compromised (Pagliuca et al., 2022). Consequently, the way values influence individuals is not universally consistent (Schwartz, 1994). For instance, households are willing to adopt cleaner sources of energy, such as solar PV, only if they are easily accessible and can offer them a cheaper alternative to conventional energy sources (Meried, 2021). Besides that, most households, especially in South Africa, are likely to remain dependent on conventional grid energy because conventional sources are readily available and cheap (Eskom, 2020). Thus, the influence of people's values on solar PV adoption needs to be complemented by other motivating factors such as financial incentives and government subsidies.

Table 3.5. Influence of values on households' intention to adopt solar PV

Value	***rho-value***
Social justice: correcting injustice, caring for the weak	0,056
Helpful: working for the welfare of others	0,094
Equality: equal opportunity for all	0,163
A world at peace: free of war and conflict	0,134
Protecting the environment: preserving nature	0,092
Preventing pollution of land, air or water	0,003*
Respecting the earth: live in harmony with other species	0,175
Unity with nature: fitting into nature	0,006*

* denotes significant relationship

3.4. Conclusion and recommendations

In conclusion, this study has identified and reported on various financial, institutional, personal, and social barriers to solar PV adoption that are experienced by urban residents in South Africa. Although most of these barriers were reported by both high and low-income urban households, low-income households tended to be disproportionately impacted by these barriers. For example, more low-income than high-income households had little knowledge about solar PV, limited financial resources to adopt solar PV, and tended not to benefit from institutional policy changes that are meant to stimulate solar PV adoption. It is unclear which set of barriers are more important than others since the majority had varied responses among both high-income and low-income households. However, there is a need to address these barriers highlighted by both high-income and low-income groups to encourage rapid uptake of solar PV adoption in South Africa across all income groups. Given South Africa's households context and existing inequalities, it is prudent to suggest that measures should be tailored to address barriers encountered by low-income households because they tend to be disproportionately affected, all the while, recognising that the barriers are interlinked and form part of a complex interplay of factors that shape people's interest in and ability to shift to solar PV systems.

Firstly, to address these barriers, the study underscores the necessity of inclusive financial arrangements such as power purchase agreements and solar PV leasing programs. Considering the high rate of unemployment in the country and the financial challenges faced by most households, equitable financial arrangements would result in widespread adoption inclusive of the low-income households who constitute most of the population in South Africa (Statistics South Africa, 2022). Thus, including low-income households in renewable energy initiatives like solar PV can offer significant potential for reducing reliance on grid energy, as they are often the most wasteful energy users due to lack of knowledge (Department of Energy SA, 2019). Secondly, comprehensive policies are needed to facilitate equitable transitions to renewable energy, aligning with the narrative of a just transition to solar PV. Policies such as feed in tariffs can help in the attainment of widespread solar PV adoption. Thirdly, to overcome the barriers such as technical, cognitive and social barriers it is important to widely disseminate information about the factors and processes involved in the installation and generation of solar PV energy as many of the barriers identified in the study are closely tied to households' lack of awareness. Information dissemination can be done by integrating solar PV knowledge into the school curriculum. Fourthly, public awareness campaigns related to solar PV could help address barriers such as limited access to reliable technical information that is faced mainly by the low-income households. Given the disparities regarding how information on solar PV is disseminated in high and low-income groups as reported in this study, awareness campaigns should take the form of community workshops initiated by NGOs, where all community member have a chance to share and acquire knowledge on solar PV systems. Lastly, while renewable energy debates are typically framed within the sustainability discourse, the paramount driver for renewable energy in South Africa is energy security. This emphasises the need for energy debates to encompass not only environmental sustainability but also factors that households prioritise, such as convenience. Thus, it is crucial to channel renewable energy interventions towards addressing what people consider most important. Though important, most value factors were not significant to solar PV adoption. Although there are several advantages to adopting solar PV, it is also important to acknowledge its drawbacks. For instance, South Africa has long been reliant on fossil-based energy which created job opportunities in the industry. Therefore, future research needs to examine how transitioning to solar PV may affect those reliant on fossil fuel jobs.

CHAPTER 4: MOTIVATIONAL DRIVERS AND EXPERIENCES OF SOLAR PV ADOPTERS AMONGST SOUTH AFRICAN HOUSEHOLDS

NOTE: *This paper has been submitted to the Energy Reports journal and it is currently under review.*

Abstract

Despite the need for renewable energy due to high dependence on high carbon energy sources, adoption of solar PV systems remains low globally and in South Africa. Barriers to solar PV adoption are framed from non-adopters' perspectives and often include myths and misconceptions. These myths and misconceptions can be attributed to limited systematic analysis of adopters' motivational drivers and experiences. Using semi-structured interviews, this study examined the key motivational drivers of solar PV adoption that are considered important for transitions to solar PV energy in South Africa. In addition, the study investigated insights and experiences of solar PV adopters. The study was conducted among households in four urban areas in the Eastern Cape province of South Africa. Results show that persistent power cuts (loadshedding) were the major motivational drivers of solar PV adoption among high-income households, while low-income households were driven by the desire to save money. In addition, peers such as neighbours played an important role in influencing solar PV adoption in both low- and high-income households. Although most solar PV adopters in both income groups were generally satisfied with their solar PV systems, most low-income households seem to have adopted solar PV systems with insufficient knowledge about how the systems function. The study recommends that debates around transitions to solar PV energy should be framed around what people consider important, which is reliable energy supply and income saving. The study also recommends investments in educating non-adopter households to consider solar PV energy so that they enjoy similar benefits as adopters.

Keywords: Renewable energy, push-factors, sustainable energy, green energy

4.1. Introduction

Conventional sources of energy, such as coal, contribute significantly to climate change due to greenhouse gas emissions at every stage of the energy supply chain, from resource mining to consumption (Marchetti-Mercer, 2023; Culiberg et al., 2023). Globally, conventional fossil-based energy generation contributes about 34 billion tonnes (Gt) of carbon dioxide (World

Nuclear Association, 2024). Estimates suggest that coal-powered energy production generates about 45% of carbon emissions, with other energy sources, such as oil and gas, contributing the remainder (World Nuclear Association, 2024). With increasing population growth, urbanisation, and the appetite for consumerism, energy demand is expected to rise, and so are the associated negative social and environmental effects linked to greenhouse gas emissions (Abbass et al., 2022; Culiberg et al., 2023). These negative social and environmental effects are likely to be more amongst developing countries that depend on conventional sources of energy. Recent studies have suggested that the adoption of renewable energy resources such as solar PV has the capacity to both meet the rising demand for energy and reduce the negative social and environmental effects linked to conventional energy sources (Chidembo et al., 2022a; Eti et al., 2024). Solar PV system uses solar photovoltaic cells to convert sunlight directly from the sun to electricity. Given the ability of solar PV to directly convert sunlight to electricity, the solar PV system is regarded as cheap and clean, with the capacity to reduce global carbon emissions (IRENA, 2022; Ahmar et al., 2022). For instance, solar PV adoption in Germany has reduced more than 40% of its 1990 levels of carbon emissions (IRENA, 2022). Similarly, solar PV systems have reduced Australian carbon emissions by 34% (Oteng et al., 2022).

Understanding motives and experiences behind solar PV adoption is important because motivations cannot be considered in isolation from experiences if we are to encourage solar PV adoption among non-adopters. There might be variations in solar PV adopters' motivation for adoption and experiences of use, which means different perceptions and impacts might require different interventions for optimal promotion and management of solar PV adoption (Shakeel et al., 2023). Neglection of adopters' experiences of solar PV can be problematic because (i) positive experiences should be recorded as empirical evidence is needed to inform policies for encouraging solar PV adoption, (ii) negative experiences are real; hence, solar PV management systems should take them into account to be meaningfully responded to. Further, negative experiences of solar PV experiences might constrain positive links between solar PV adoption and people's wellbeing. Additionally, the expected benefits of solar PV might be achieved through addressing the negative impacts experiences rather than through encouraging adopters to improve capacity. Thus, a one-sided approach to the benefits of solar PV is insufficient to address the negative experiences adopters might face. Therefore, there ought to be a wider recognition of the experiences of solar PV adopters as a basis for improving future programmes aimed at encouraging solar PV adoption. The aim of this study is to document the motives of solar PV adoption that are considered most important by adopters when shifting to solar PV. Further, we investigated the experiences of solar PV adopters in using solar PV in their homes. Results of this study provide useful insights needed to inform solar PV adoption programmes that speak to the needs and values of consumers and, in turn, make programmes appealing and useful to consumers and ultimately facilitate the transition towards wider adoption of solar PV technology. Key questions of the study were:

1. What are the primary motivational drivers of solar PV adoption among South African households in Eastern Cape province?
2. What are households' experiences of using solar PV in the Eastern Cape province of South Africa?
3. What are the implications of findings on solar PV adoption?

Motivational drivers of solar PV adoption

The significant growth of solar PV adoption among households is attributed to several driving factors including energy security and independence (IEA, 2020; Ali et al., 2020), affordability (Herman et al., 2023; Milewska and Milewski, 2023), social influences (Poruschi and Ambrey, 2019) and sustainability concerns or environmental effects of conventional energy sources (Marchetti-Mercer, 2023; Culiberg et al., 2023). Solar PV-generated energy is a dependable energy source characterised by durable components and extensive warranties, which ensure their reliability as an energy source (IEA, 2020). Thus, the need for a reliable source of energy is one of the most significant motivational drivers of solar PV adoption among households (Ugulu et al., 2019). For example, the persistent grid energy power cuts in Nigeria have resulted in most households opting for solar PV systems as they regard it as a reliable energy source (Ugulu et al., 2019). Similarly, in Pakistan, most households perceive solar PV as a reliable energy source that ensures energy independence (Qureshi et al., 2017; Ali et al., 2020).

Apart from energy reliability and independence, some studies have also suggested that solar PV adoption is driven by the need to save money (Herman et al., 2023; Milewska and Milewski, 2023). According to a report by IEA (2020), solar PV systems offer the cheapest form of energy compared to coal and gas in most countries around the globe. Although solar PV systems offer long-term returns on investment, literature reports that some households consider it as a cost-effective and saving alternative to grid energy (Qureshi et al., 2017; Herman et al., 2023; Milewska and Milewski, 2023). Solar PV systems are also durable and need minimal maintenance, which further validates their value as a cheap form of energy (Herman et al., 2023). Considering the constant decrease in prices for solar PV resources, solar PV now offers an attractive long-term compensation, as reported by Milewska and Milewski (2023) among Polish households and Herman et al. (2023) among European Union households.

Other studies also suggest that solar PV adoption among households is driven by social factors, such as peer influence (Walters et al., 2018; Poruschi and Ambrey, 2019; Dhoha and Ramendra, 2019). Social factors refer to the societal pressure individuals face to conform to certain behaviours (Poruschi and Ambrey, 2019). Peers such as neighbours, eagues, and influential individuals in society, play a crucial role in this dynamic (Dhoha and Ramendra, 2019). For instance, studies in Australia found that solar PV distribution was strongly affected by the availability of solar PV energy among peers (Poruschi and Ambrey, 2019). The above study observed that people's behaviours are highly influenced by the behaviour or expectations of people that surround them. Walters et al. (2018) report similar findings among Chilean households, where they found that most households that were considering adopting solar PV reported previous persuasive discussions with solar PV owners who had already adopted solar PV in the same area. These findings have also been confirmed by Rai et al. (2016) in northern California, who coined the term "neighbour-related spark." Results from the above-mentioned studies seem to suggest that neighbourhood peer effects are very important in providing valuable technical information to potential solar PV adopters. Thus, societal expectations are influential in motivating households towards solar PV adoption.

Apart from social influences, socio-demographic factors, including income, education level, age, and gender, play a significant role in influencing solar PV adoption among households (Guta, 2018; Etongo and Naidu, 2022). For instance, a study conducted in Ethiopia found that most solar PV adoption was highly influenced by households' access to credit facilities, a scenario which favoured mainly high-income households (Guta, 2018). Similar findings were also reported among households in Seychelles (Etongo and Naidu, 2022). In Pakistan, socio-demographic factors such as age and gender influenced households to trust solar PV adoption (Saleem and Zhang, 2024). The above-mentioned study reported that females were more receptive to solar PV initiatives than males due to differences in socialisation (Saleem and Zhang, 2024). Apart from socio-demographic factors, environmental concern has also been identified as a motivational driver of solar PV adoption among households (Qureshi et al., 2017; Wolske et al., 2017; Palm, 2018; Ghosh and Prasad, 2024). For example, in a review of the motivational drivers of solar PV adoption among households in India, Ghosh and Prasad (2024) found that reduced carbon footprint was one of the key motivational drivers. Among British households, McKenna et al. (2018) found that the decision to adopt clean sources of energy (for which solar PV is one of them) was driven by the desire to reduce greenhouse gas emissions. Similar findings were reported by Wolske et al. (2017) among American households, where a strong correlation was reported between households that had strong environmental values and solar PV adoption. This implies that environmental concern plays a fundamental role in motivating households to adopt solar PV. Among other motivational drivers of solar PV adoption, personal values also play a role in people's energy choices. Values are regarded as life goals that guide life principles (Poortinga et al., 2004). They are categorised into two main dimensions, namely openness to change versus conservatism and self-enhancement versus self-transcendence (Schwartz, 1994). Literature suggests that individuals with conservative values are less likely to engage in behaviours that favour the environment (e.g., solar PV) due to their preference for maintaining routines and immediate gains (Schwartz, 1994). Conversely, those with self-transcendent values are more receptive to new ideas, making them more likely to adopt innovations like solar PV (de Groot and Steg, 2007; Frederiks et al., 2015). Thus, people with self-transcendent values are intrinsically driven to adopt solar PV systems because of their openness to change and concern for the environment. Besides the driving factors, literature also notes that solar PV adopters face challenges that could significantly impact potential adoption among non-adopters (Shakeel et al., 2023).

Challenges faced by solar PV adopters

Although several incentives for solar PV adoption have been discussed above, several solar PV adoption challenges have been documented (Lan et al., 2020; Kapoor and Dwivedi, 2020; Shakeel et al., 2023). These are mostly categorised as technical, social, and institutional challenges. Technical challenges faced by household solar PV adopters are diverse (Qureshi et al., 2017; Arroyo and Carrete, 2019; Kapoor and Dwivedi, 2020; Agaja et al., 2020), with one of the challenges being the failure of solar PV components to perform as expected (Kapoor and Dwivedi, 2020; Agaja et al., 2020). For instance, a study in Nigeria found that some households acquired cheap solar PV systems that did not have a long lifespan (Agaja et al., 2020). Other technical challenges faced by solar PV adopters include lack of localised points for solar PV spares or repairs (Sovacool et al., 2011; Ohunakin et al., 2014). For instance, in the Delta region of Nigeria, as might be the case across Africa, most solar PV appliances are imported from overseas, and there were no localised points where households could get spares, thus, households have to import spares which makes solar PV adoption expensive (Ohunakin et al., 2014). Apart from technical challenges, social challenges such as theft and vandalism pose significant threats to the sustainability of solar PV systems (Ikejemba and Schuur, 2018; Raymond et al., 2022). Ikejemba and Schuur (2018) specifically examined the impact of theft and vandalism on solar PV systems in sub-Saharan countries, emphasising their detrimental effects on sustainability. Social challenges such as theft and vandalism have also been reported among households in Nigeria (Agaja et al., 2020) and Tanzania (Raymond et al., 2022). In Nigeria, particularly in the Delta region, literature reports that solar PV adopters faced recurring incidents of theft, with the stolen PV systems often being resold to suppliers at reduced prices (Agaja et al., 2020). Similarly, in Tanzania, cases of theft and vandalism of solar PV systems were also prevalent (Raymond et al., 2022), thus, solar PV was deemed a risky investment by some households, thus slowing down the adoption process.

Apart from social challenges, issues of inconsistent solar PV adoption policies have been identified as a challenge (Bermudez, 2018; Lan et al., 2020; Castro-Rodríguez and Miles-Touya, 2023; Ibegbulam et al., 2023). Studies conducted in Spain (Castro-Rodríguez and Miles-Touya, 2023) and Australia (Lan et al., 2020) have shown that households face challenges regarding inconsistent feed-in policies when attempting to sell excess solar PV energy back to the grid, thus deterring investment in solar PV systems by households. In Japan, there is a reported lack of institutional support from both the government and energy companies to promote solar PV (Bermudez, 2018). For instance, monopolistic electricity sellers in Japan get most of their revenue from fossil energy sales and, thus, have limited support for renewable energy sources such as solar PV, which makes it difficult for households to transition to solar PV (Bermudez, 2018).

4.1.1. The South African energy context

South Africa is one of the most energy-intensive countries in Africa (Eskom, 2019; 2020), and the main energy service provider, Eskom, has faced a substantial maintenance backlog, which leads to frequent power shortages. These power shortages tend to significantly affect households and small businesses that do not have alternative energy sources and are dependent on conventional energy (Esterhuizen, 2019). The company also generates over 90% of its energy from low-quality coal, which contributes significantly to the country's carbon emission factor, thus posing environmental concerns (Eskom, 2023). Calls for South Africa to transition towards renewable energy sources such as solar PV have intensified due to benefits such as energy security, carbon emission mitigation, and opportunities for the country to meet its environmental and international obligations. Although the South African government has implemented strategies to promote solar PV adoption, e.g., tax rebates, the rate of adoption is still low due to multi-dimensional challenges (McKay and Hendricks, 2022; Chidembo et al., 2022a). Current estimates suggest solar PV contributes less than 5% to the country's energy mix (IRENA, 2022) and has been adopted by approximately 10% of households (IRENA, 2022). There is a perception that the existing government incentives towards solar PV adoption seem to benefit high-income households as compared to low-income, yet the latter need more support due to limited financial resources (Statistics South Africa, 2022). Most studies on solar PV adoption in South Africa tend to examine opportunities and challenges faced by non-adopters (McKay and Hendricks, 2022; Chidembo et al., 2022a), yet an assessment of motives and experiences by adopters could give deeper insights that could inform policies towards a just transition to renewable energy.

4.2. Methods

Study sites

The study was conducted in two cities (Gqeberha and East London) and big towns (Makhanda and Komani) that are in the Eastern Cape province of South Africa (Figure 4.1). The above-mentioned two cities are located within metropolitan municipalities. In South Africa, metropolitan municipalities are responsible for executing all local government functions within their jurisdiction (Britannica eds, 2024). On the other hand, big towns are significant urban centers that are smaller than metropolitan cities but still play a key role in the country's economy and governance (Britannica eds, 2024). The study cities and towns were purposively selected to represent diverse socio-economic characteristics. Gqeberha is located within the Albany thicket and fynbos biome, which is characterised by a combination of dense, semi-succulent shrubs and trees and floral vegetation such as the proteas (Mucina and Rutherford, 2006). Its population is approximately 1,280,550, with a population density of about 2,572 individuals per square kilometre (Statistics South Africa, 2022). East London is located within the Albany thicket biome and has a population of around 403,581 and a population density of approximately 1,720 people per square kilometre (Statistics South Africa, 2022). Makhanda, previously called Grahamstown, is a medium-sized town situated within the Albany thicket biome (Mucina and Rutherford, 2006). It has a population of about 75,170 people and a population density of about 1,034 individuals per square kilometre (Statistics South Africa, 2022). Komani, previously known as Queenstown, is a big town located within a grassland biome (Mucina and Rutherford, 2006). It has a population of approximately 122 365 people and a population density of around 957.4 people per square kilometre (Statistics South Africa, 2022).

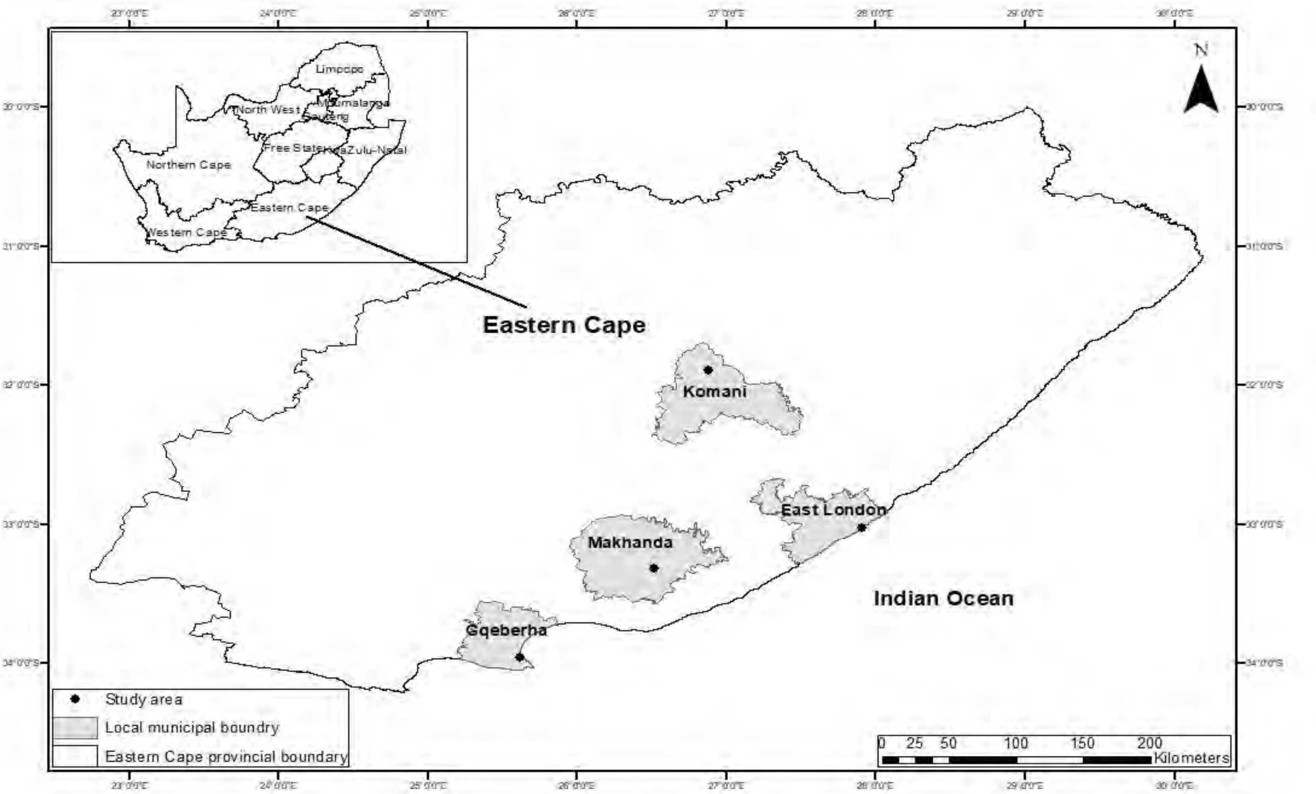

Figure 4.1. Location of the four study cities and towns in Eastern Cape province of South Africa.

The Eastern Cape province is characterised by high poverty (61%) and unemployment rates (33%), correlating with high levels of illiteracy (Statistics South Africa, 2022). Over 40% of households in the province are recipients of the government's social grants, financial assistance given to selected low-income households to alleviate poverty (Statistics South Africa, 2022). The Eastern Cape province receives the highest amount of free basic electricity, which is a government initiative that provides 50 kWh of free power to low-income households to combat energy poverty (Eskom, 2021; Mukumba and Chivanga, 2023). Like other South African urban settings, the study cities and towns exhibit a two-tiered social structure: high and low-income households (Finn et al., 2014). High-income neighbourhoods are characterised by big houses located on big pieces of land, compared to low-income households, which have small houses on small pieces of land. In addition, high-income neighbourhoods are associated with good educational schools and social services compared to low-income households. A key characteristic of low-income households is the government-built RDP houses, for which some of them benefited from the government's Solar Water Heating Programme initiated in 2008 which saw qualifying houses receiving free Solar Water Heaters.

4.2.1. Data collection

In each study city and town, 20 high-income and 20 low-income households with solar PV systems were randomly selected. Random selection was done using Google Earth images for the selected cities and towns. It is important to acknowledge that Google Earth is prone to inaccuracy in identifying ground features, including the potential for outdated information, hence, ground truthing was conducted for validation purposes and to verify if the solar PV panels were available on houses. To select the participating households, each household with solar PV appearing on Google Earth was assigned a number, and a random list was then created using the RANDBETWEEN function in Microsoft Excel. The randomly selected households were then approached for interviews, and if a selected household was unavailable or unwilling to participate in the study, the next available randomly selected household with a solar PV system was approached. Within each selected household, a willing household head was approached to collect information on motivations for, knowledge, and experiences of solar PV adoption. Although we targeted 160 households across all cities and towns (20 high-income and 20 low-income households in each of the four study towns), only 106 households participated in the study. A substantial number of respondents in high-income households were unwilling to participate for either personal reasons or security considerations. Data collection was undertaken between 9 AM and 5 PM (Monday – Saturday) from November 2022 to December 2023.

The structured questionnaire (see appendix 4.1) was divided into sections meant to collect data on the socio-demographic profile of the sampled population, motivation for solar PV adoption, knowledge of solar PV, and respondents' value orientations. Socio-demographic information included gender, age, education, income level, and household size. Data on households' motivations were collected by asking questions such as, "*what motivated you to adopt solar PV?*" The level of knowledge was assessed by asking respondents' knowledge of technical dimensions of solar PV with responses on a three-point Likert scale (knowledgeable, partially knowledgeable and unknowledgeable). Participants were considered knowledgeable if they exhibited a detailed understanding of the technical process behind solar PV generation. Those falling under the partially knowledgeable group had surface idea of how solar PV works but lacked the technical details. The respondents were considered unknowledgeable if they reported no understanding of how the solar PV system functions. The questionnaire also captured the respondents' value orientations. To assess solar PV adoption and respondents' worldly views, life assumptions, and perceptual orientation, respondents were requested to assess their set of personal value orientations using a five-point Likert scale (ranging from 1 = unimportant to 5 = critical) following Mutumbi et al. (2021). Individual scores nearing 1 and 5 indicating a low and high disposition towards the specific value orientation, respectively. The research was conducted following ethical approval of the research and questionnaire by the Rhodes University Ethics Committee (Review reference number 2022-5895-7199).

4.2.2. Data analyses

Responses were firstly recorded in an excel spreadsheet and were analysed using Statistica Version 14 (TIBCO Software Inc, 2019). The socio-demographic profile of the sample population was analysed using descriptive statistics and presented using a table. Differences in means of numeric socio-demographic data, such as age and household size, were analysed using T-tests between income groups. A Pearson correlation analysis was used to test associations of interest, such as the relationship between solar PV adoption and explanatory factors such as knowledge levels, social influences, and value orientations. Transcriptions of interview responses were analysed using thematic analysis to extract key insights, following Braun and Clarke (2006). The initial stage identified emerging trends related to the adoption of solar PV adoption. In the second stage, data were thoroughly examined, and codes were generated. The third stage involved clustering these codes into potential themes. During the fourth stage, these potential themes were reviewed and refined, and themes lacking sufficient data were discarded, and overly broad themes were subdivided. In the final stage, themes were named and defined to accurately reflect their core concepts. Correlation analysis was conducted to assess the relationship between people's values and their decision to adopt solar PV. A reverse coding was conducted on variables related to the risks of adopting solar PV.

4.3. Results

4.3.1. The profile of the sample population

There were more males (63%) than females (37%) among the high-income respondents (Table 4.1). Conversely, there were more females (66%) than males (34%) among the low-income households. The mean age for the high-income group was significantly higher (55.6±14.36) than that for the low-income households (49.16± 16.8) (T = 2.05; p = 0.04). The mean household size for the low-income households (4.9±2.6) was significantly higher than that for the high-income households (3.2 ± 1.4) (T = 3.86; p = 0,001). Literacy levels were significantly higher among the high-income group compared to the low-income group, with most high-income respondents having tertiary education (87%) compared to 5% in the low-income group (Table 4.1). Comparatively, literacy levels were generally low amongst low-income households, with most respondents having attained only primary (29%) and secondary (66%) education. About 82% of all high-income respondents were employed. Of these, nearly half (49%) were business owners, and a third (33%) were formally employed, earning wages and salaries. In contrast, only 10% of low-income were employed (earning wages and salaries) with the bulk (85%) receiving government social grants (income from the South African government offered to marginalised communities to mitigate the adverse impact of poverty). Nearly 18% of the respondents in high-income areas were pensioners compared to only 5% in the low-income group. Most high-income households (84%) had a monthly income of more than ZAR30 000.00 (US$1565.67 using the June 2024 exchange rate), while almost all low-income households (95%) earned less than ZAR6 000 (US$313.14 using the June 2024 exchange rate) per month.

Table 4.1. The profile of the sample population.

Attribute	**High-income (n= 47)**	**Low-income (n= 59)**	**All (%)**
Gender (%) of respondents			
Female	37	66	51
Male	63	34	49
Mean age of respondents (%)	55.6 ± 14.4	49.1 ± (16.8)	52.9 ± (16)
Mean household size	3.2 ± 1.4	4.9 ± (2.6)	4. 1± (2.2)
Level of education (%)			
Primary	-	29	14.5
Secondary	13	66	39.5
Tertiary	87	5	46
Household income (%)			
Own business	49	-	24.5
Pensioners	18	5	11.5
Social grants	-	85	42.5
Wages/salary	33	10	21.5
Household monthly income (%)			
<2000	-	54	27
2001-6000	2	41	21.5
6001-15,000	-	5	2.5

15,001-30,000	14	-	7
>30,000	84	-	42

4.3.2. Solar PV adoption and its motivational drivers

Nearly two-thirds of the high-income households (61%), compared to only 2% in the low-income households, adopted solar PV in the past three years (2021-2023) (Table 4.2). In contrast, most respondents in the low-income group (98%) adopted solar PV more than three years ago, compared to only 39% in the high-income group. All the high-income respondents installed solar PV systems privately, whilst nearly all low-income households (97%) were beneficiaries of the government-initiated solar PV programmes, mostly for solar heating purposes. When respondents were asked about the motivation behind solar PV adoption, most high-income households (85%) cited power cuts as their main reason. Both environmental concern and the ability to save money were mentioned by less than 10% of the respondents in high-income areas. Most respondents in the low-income areas (46%) cited the ability to save money as the main adoption reason; this is likely linked to the motive behind the government solar heating installation program since most of them benefited from this programme. Apart from that, nearly 10% and 8% of low-income households mentioned power cuts and environmental concerns, respectively (Table 4.2).

Table 4.2. Solar PV and its motivational drivers.

Attribute	**High-income (n=47)**	**Low-income (n=59)**	**All (n=106)**
Period since adoption (%)			
In the past 3 years	61	2	31.5
More than 3 years ago	39	98	68.5
Source of adoption (%)			
Private	100	3	52
Government initiative	-	97	48
Reasons for adoption (%)			
Power cuts	85	10	47
Environmental concerns	9	8	9
Saving money	7	46	26

4.3.3. Knowledge of solar PV systems

Most high-income respondents (88%) were knowledgeable of solar PV systems including technical functions such as storage and generation capacity (Table 4.3). In contrast, most of the low-income households (86%) reported no knowledge of solar PV functionality (Table 4.3).

Most high-income households (80%) possessed prior knowledge regarding the solar PV capacity required to sustain their households before installing solar PV systems. However, all the surveyed low-income households lacked such information. About half (48%) of the high-income respondents acquired their knowledge through the internet and TV adverts compared to 28% in the low-income households (Table 4.3). The bulk of the low-income households (66%) receive their information about solar PV from installers and suppliers (Table 4.3) thus, through the government-initiated solar heater installation companies.

Table 4.3. Knowledge and source of knowledge of solar PV.

Attribute	**High-income (n=47)**	**Low-income (n=56)**	**All (n=106)**
Knowledge of solar PV (%)			
Knowledgeable	88	14	51
Basic knowledge	-	-	-
No knowledge	12	86	49
Knowledge on capacity needed to support household needs (%)			
Yes	80	-	40
No	20	100	60
Source of knowledge (%)			
Installers and suppliers	22	66	44
Friends and neighbours	30	6	18
Internet/Tv adverts	48	28	38

4.3.4. Social influences on solar PV adoption

The respondents were asked to indicate their agreement with a set of questions regarding the influence of social factors on their decision to adopt solar PV. The results showed that most high-income (74%) households strongly disagreed that their family members were opposed to solar PV adoption (Figure 4.2). On the other hand, most low-income (80%) income households disagreed that their family members were opposed to solar PV adoption. When households were asked on whether important people to them would adopt solar PV for their households, about 44% among the high income strongly agreed, whilst about 85% among the low-income agreed that important people to them would adopt solar PV for their households. When respondents were asked on whether important people to them supported their decision to adopt solar PV, close to half (46%) among the high income strongly agreed while 83% among the low income agreed that important people to them supported their decision to adopt solar PV systems.

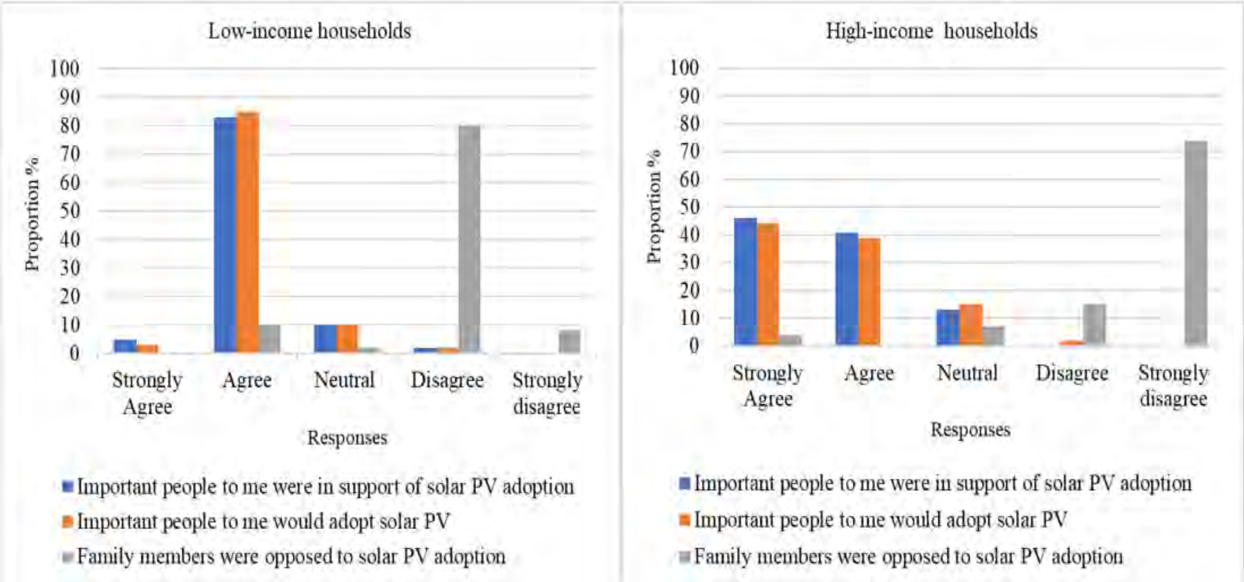

Figure 4.2. Social influences on solar PV adoption.

4.3.5. Perceptions and experiences of the solar PV systems

This study investigated the perceptions of adopters regarding maintenance costs, security, and performance of solar PV systems. Responses showed that nearly half of high-income households (44%) strongly disagreed, while most low-income households (63%) disagreed that solar PV systems were expensive to maintain (Figure 4.3). When households were asked about the security concerns regarding their solar PV systems, a sizable proportion high-income households (33%) agreed that the security of their systems was a concern, however, more than half (54%) of them disagreed that security was a concern. When households were asked whether solar PV systems performance was affected by weather, most of both high-income households (45%) and low-income households (39%) disagreed. When respondents were asked on whether solar panels affected the aesthetics of their rooftops, most high-income households (57%) strongly disagreed, while a majority of the low-income (85%) disagreed. Further, when respondents were asked on their level of satisfaction with the solar PV systems, a high proportion of both high-income (95%) and low-income households (88%) were satisfied.

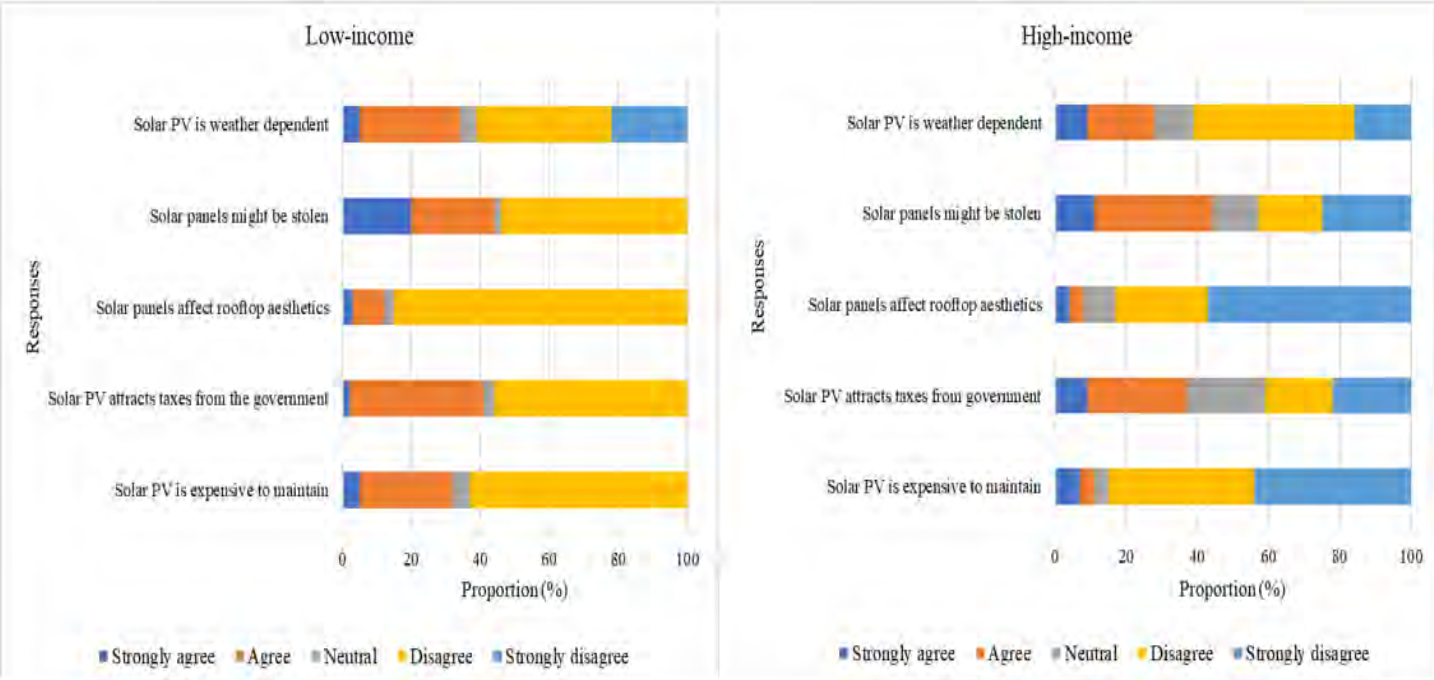

Figure 4.3. Perceptions and experiences of solar PV systems.

4.3.6. Perceptions of institutional challenges

Respondents were asked if there were any policies available that supported solar PV adoption, some (79%) of high-income households felt there were no supportive policies (Table 4.4). However, a very high proportion (91%) of low-income households perceived there were supportive policies. Concerning the easiness of solar PV adaptors to supply surplus electricity to the national grid, about 43% of high-income respondents reported that the process was either difficult or very difficult, compared to only 27% in the low-income households (Table 4.4). A substantial proportion (63%) of the low-income respondents were not sure about the easiness of solar PV supply to the national grid. When households were asked about the possibility of government taxation on solar PV systems, high-income households exhibited mixed feelings. About 41% disagreed, while 22% were unsure, and 37% agreed. For low-income households, more than half (56%) disagreed, while 41% agreed and 3% were unsure that the government would tax them.

Table 4.4. Institutional challenges reported by households.

Attribute	High-income (n=47)	Low-income (n=56)	All (n=106)
Availability of supportive policies (%)			
Yes	17	91	54
No	79	9	44
Not sure	4	-	2
Supplying solar PV energy to the national grid (%)			
Very easy	17	2	10
Easy	19	8	13
Not sure	21	63	42
Difficult	17	17	17
Very difficult	26	10	18
Solar PV attracts taxes from the government (%)			
Strongly Agree	9	2	6
Agree	28	39	34
Neutral	22	3	12
Disagree	19	56	37
Strongly disagree	22	-	11

4.3.7. The influence of values on solar PV adoption

The association between respondents' solar PV risk perception and pro-environmental values was tested using a correlation analysis. Most people's value orientations were not positively correlated with solar PV adoption (Table 4.5). However, a positive significant correlation (rho= 0.36; p= 0.01) was found between pro-environmental values and concern for the environment among high-income households, meaning most high-income respondents who are concerned about the environment tend to adopt solar PV (Table 4.5). Amongst low-income households, a significantly positive correlation (rho= 0.50; p< 0.001) was found between pro-environmental values and concern over aesthetics, meaning households that value aesthetics are likely to adopt solar PV. Generally, the lack of correlation between respondents' solar PV adoption perception and pro-environmental values implies that human values are not the main reasons behind solar PV adoption.

Table 4.5. The influence of pro-environmental values on risk perception of solar PV adoption.

Risk perception	Income group			
	High-income		**Low-income**	
	rho-value	*p-value*	*rho-value*	*p-value*
Lack of familiarity	0.10	-0.67	0.22	0.08
High maintenance costs	-0.12	0.39	0.09	0.46
Government taxes	0.05	0.72	-0.03	0.84
Aesthetic concerns	-0.24	-1.66	0.50	<0.001*
Theft of solar PV system	0.07	0.46	0.04	0.74
Concern for the environment	0.36	0.01*	0.10	0.42
Bad weather	0.07	0.44	0.07	0.60

4.4. Discussions and implications

4.4.1. Solar PV adoption and its motivational drivers

The period in which most high-income households adopted their solar PV systems coincides with the period of persistent power cuts in South Africa (2021 – 2023); for example, approximately 1 742 hours of power cuts were experienced in 2023 (Eskom, 2023; Businesstech, 2024). This pattern seems to suggest that power cuts could have been the major driver behind solar PV adoption in the study area, as was shown among high-income households. These results are also consistent with findings in Nigeria (Ugulu et al., 2019) and Pakistan (Ali et al., 2020), which show that the transition to solar PV by some households is motivated by the need to gain grid independence and a reliable source of energy. Solar PV systems are regarded as a reliable and durable energy source; this is likely to explain why some households are adopting solar PV and migrating from grid energy. Unlike high-income households, most low-income households benefited from government-initiated solar PV programmes that provided solar PV systems starting in 2008 to alleviate energy demand (IEA, 2020), which could explain the differences in both the time of installation and motivational drivers of solar PV adoption between high and low-income households. For instance, for high-income households, the primary motivation was to mitigate the impact of the disruptive power cuts probably because they value convenience and have a comparatively very high dependence on energy for various aspects of their lifestyle (Herman et al., 2023; Milewska and Milewski, 2023). In a context of up to 10 hours of daily power cuts (World Bank, 2024), households that can afford are compelled to seek reliable options (Dube and Viljoen, 2024). Perhaps low-income households do experience the impact of the disruptive power cuts but do not have the financial means and motivation to adopt solar PV due to costs.

4.4.2. Knowledge of solar PV systems

The lack of information regarding solar PV systems by households in low-income areas where the bulk of the solar systems were donated by the government shows that the government may have donated these systems without transferring information about how the system functions. Initiatives such as solar PV adoption need to be accompanied by engaged education and awareness so that households can understand the system and its potential benefits. Similar findings were also reported by Bikam and Mulaudzi (2006), who found that households in Folovodwe, South Africa, received solar PV systems through a government pilot programme but lacked the necessary operational knowledge, resulting in dissatisfaction and a lack of interest. Most low-income households had limited knowledge on solar PV systems, implying that there is limited educational involvement of households in government-initiated programmes. The results concur with the findings by Netshiozwi (2019), who attributed the failure of the solar water heating programme in Alexandra and Soshanguve to a lack of proper training to operate the systems, resulting in wrongful use and eventual breakdown of the systems.

Overall, these results highlight the need for education, especially among low-income households who have limited access to reliable and consistent sources of information. Educating households can take various forms, including awareness campaigns conducted through established community forums, social media platforms accessed by everyone, vocational training, or integration into the school curriculum. For instance, the United States' Solar Energy Technologies Office (SETO), a division within the Department of Energy, successfully implemented an inclusive solar PV awareness campaign, which helped in promoting solar PV adoption among a diverse audience (US Department of Energy, 2022). Solar PV distribution companies need to make sure that adopters have adequate information on the functionality of the systems to avoid dissatisfaction and damage to appliances due to wrongful use. Indeed, the results of this study show that a relatedly large number of households in both the high- and low-income groups are getting solar PV-related information from installers and suppliers. Training and capacity-building initiatives by both suppliers and the government play a pivotal role in empowering local communities and, thus, stimulating investment in solar PV energy (Macharia, 2024). Moreover, solar PV companies also need to conduct some pre-installation household energy requirement checks to avoid misalignment between household needs and solar PV system capacity. Pre-installation analyses are quite common in India where solar PV installers educate households as well as conducting systems checks before the final installation process (Pandey et al., 2022).

4.4.3. Social Influences on solar PV adoption

The study has also highlighted the influence of socio-psychological factors such as neighbours and relatives on households' decision to adopt solar PV. These results are supported by findings from similar studies (Walters et al., 2018; Poruschi and Ambrey, 2019). For instance, studies in Australia by Poruschi and Ambrey (2019) found that solar PV distribution was strongly affected by the availability of solar PV energy among peers. The basic argument in the above-mentioned study was that the behaviour of individuals is highly influenced by the behaviour or expectations of important people surrounding them. Walters et al. (2018) reported similar findings among Chilean households, showing that most households that were considering adopting solar PV had convincing discussions with solar PV owners, which often resulted in households with solar PV being clustered in the same area. Rai et al. (2016) refer to this behaviour as "neighbour-related spark," implying that households share information through social learning, thus projecting a good solar PV image that stimulates others to adopt the system. Literature also shows that households in Vaud Canton, Switzerland, had an 89% chance of installing solar PV systems if they knew other households who had adopted them (Serra-Coch et al., 2023).

Thus, an understanding of the role of social learning and peer influence in stimulating the adoption of new technologies such as solar PV might support efforts for solar PV adoption. Social collaborative interventions such as workshops, where community members learn and encourage each other to adopt solar PV and the use of local champions, can increase the chances of solar PV adoption (Serra-Coch et al., 2023). Government policymakers need to convince community leaders to play a leading role in the adoption of solar PV among households. Once peer influence and stimulation have happened, initiatives such as government-driven group purchases and installation incentives have the potential to increase adoption within the same neighbourhoods. This could help to reduce the start-up costs as well as create visible clusters for solar PV adopters, thus enhancing the "neighbour-related spark" effect. The government can also initiate pilot projects in targeted communities to create initial clusters of solar PV adopters. These cluster projects can work as practical demonstrations of the benefits of solar PV systems and can foster wider adoption within a community (Jumayev and Atayev, 2022).

4.4.4. Perceptions and experiences of the solar PV systems

A reflection on the experiences of solar PV users indicates that they were generally satisfied with their systems, which demonstrates their reliability as a source of energy. These results are consistent with findings elsewhere (Ugulu et al., 2019; Ali et al., 2020). For instance, in Nigeria, households perceive solar PV systems as more reliable than grid energy and diesel/petrol generators (Ugulu et al., 2019). Moreover, results have also demonstrated that solar PV systems need minimal maintenance, aligning with findings by Shakeel et al. (2023). While operational costs are possible, they are often less burdensome than commonly perceived (Ali et al., 2020; Shakeel et al., 2023). This perception might be a result of the low maintenance requirements for solar PV and improved technology. Herman et al. (2023) suggest that solar PV systems are durable and need minimal maintenance, which further validates their value as a cheap and reliable form of energy.

Variations in responses between the high-income and low-income households pertaining to the security of solar PV systems might indicate broader security concerns in South Africa rather than the insecurities inherent in the solar PV initiative itself. For instance, the crime index in South Africa is 75.5% which places the country among the top five countries in the world with the highest rates of crime (Statistics South Africa, 2022). To gain the confidence of adopters, solar PV distributors in developed countries now distribute solar PV systems with technical security measures such as anti-theft fasteners in addition to security lighting, such as motion-sensor-connected floodlights (Unbound solar, 2020). Ikejemba and Schuur (2018) recommend human security measures, which involve the commissioning of individuals contracted to survey all solar PV-installed neighbourhoods. Similar arrangements can be employed among South African neighbourhoods, e.g., as part of the solar PV warranty, solar PV distributors and suppliers can work with security companies to offer discounted monitoring services, and the costs of security could be factored in the overall cost of solar PV systems. Households' perception of solar PV as a non-weather dependent is important in understanding the potential for solar PV adoption in South Africa. South Africa has a favourable climate for solar PV energy due to its high solar irradiance levels (Mahlobo et al., 2019). Thus, the government needs to reinforce this perception by providing enough and accurate information on the reliability and efficiency of solar PV systems under various weather conditions.

4.4.5. Perceptions of institutional challenges

Most high-income household solar PV users indicated facing challenges linked to insufficient supportive legislation. This is consistent with reports from previous studies (Nwaigwe et al., 2019; Viljoen and Dube, 2023; Macharia, 2024) that have suggested that South Africa lacks coherent policies guiding the transition to solar PV, which has consequences on both households, municipalities, and all the stakeholders benefiting from conventional energy sales. For example, there is no clear national legislation that regulates how households can migrate to solar PV and disconnect from the national grid (Viljoen and Dube, 2023). This may cause uncertainty among adopters, e.g., solar PV adopters who have gone completely off-grid are not clear on their obligation to continue paying municipal service charges for the services they no longer use (Viljoen and Dube, 2023). The positive view pertaining to the availability of supportive legislation among low-income households can be attributed to government solar programmes that benefitted low-income households only. In 2008, the government, through the Solar Water Heating programme donated solar water heaters to low-income households as a way of alleviating energy demand (IEA, 2020). Thus, there is a need for comprehensive, binding policies clearly specifying how the adoption process should be conducted. Results of this study also show that there are significant institutional barriers to solar PV adoption in South Africa. For instance, the non-availability of opportunities for households to supply to the national grid points to restrictive regulatory frameworks and a lack of supportive policies and guidelines for integrating solar PV into the existing infrastructure. Further, the high proportion of respondents who were not knowledgeable about the national grid functions among low-income households points to the need for educating households on how renewable energy sources such as solar PV can be integrated into the existing energy infrastructure.

Taken together, these results show the presence of institutional barriers faced by South African households regarding solar PV adoption. The non-availability of clear regulatory frameworks and supportive renewable energy policies are common institutional barriers faced by developing countries (Nwaigwe et al., 2019; Macharia, 2024). For instance, in Nigeria, Nwaigwe et al. (2019) postulate that households face the reality of restrictive policies and inadequate grid infrastructure, which impedes households from selling surplus energy to the national grid. Similar findings were reported in Haiti (Perry, 2020). Thus, promoting the uptake of solar PV systems requires creating clear and unrestrictive frameworks which can incentivise the participation of households and the private sector in general into the energy industry. The variability of responses between high- and low-income households pertaining to possible government taxation on solar PV systems further confirms the uncertainty stemming from the non-availability of comprehensive policies guiding the adoption of renewable energy among South African households (McKay and Hendricks, 2022; Serra-Coch et al., 2023). Though both high-income and low-income households were not certain about the possibility of government taxes on solar PV, the levels of uncertainty were lower among the low-income households, possibly because they received their solar PV systems as donations from the government and, thus, presumed that the government would not tax them.

4.4.6. The influence of values on solar PV adoption

An investigation on the contribution of values on households' decision to adopt solar PV indicated that concern for the environment played a role in the decision to adopt solar PV among high-income households. This result is consistent with Philippssen et al. (2017), who found similar impacts of income stability and environmental concern among Brazilian households. Further, similar findings were reported by Fairbrother (2012), who suggested that high-income households have access to information that can make them more conscious about the environment. The results showed that low-income households were less concerned about how solar panels would look on their rooftops, implying that they were more focused on other factors, such as the cost and benefits of solar PV systems. However, most value factors were not linked to households' decision to adopt solar PV among households, implying that, though they are important, values are not the main factor that drove them to adopt solar PV. Other factors, such as power cuts and the long-term financial benefits, might have contributed. Our findings suggest the reason why most households adopted solar PV systems, especially high-income households, was for convenience purposes. The country has experienced long hours of power cuts, which have forced financially able households to resort to solar PV (Businesstech, 2024). Therefore, if the country is to achieve more adoption rates, transition debates should be aligned with what people consider important (i.e., addressing the adverse effects of power cuts). In South Africa, the transition to renewable is framed within the sustainability discourse (IRENA, 2022), which might not be the immediate driver of solar PV adoption.

4.5. Conclusions

In conclusion, this study has advanced our understanding of the motivational drivers and experiences of solar PV adoption in the Eastern Cape province of South Africa. The study has provided empirical data that emphasises the motives behind solar PV adoption as well as the importance of information dissemination and developing adoption policies that cater to the needs of different income groups of society, which aligns with just transition principles. The study found that high-income households are primarily motivated by the desire for a dependable source of energy when adopting energy, while low-income households are motivated by the desire to save money, though most of their systems in low-income areas were donated by the government. This distinction indicates that solar PV transition discussions need to prioritise the different issues and requirements of different income groups if more adoption is to be assumed. Further, the study has highlighted the significance of social influences such as neighbours in driving solar PV adoption. Though the contribution of people's values cannot be downplayed, the practical reasons for solar PV adoption were more important than aesthetic or other value-based concerns for many households. The study also reflects that most households are generally satisfied with the performance of their solar PV systems. However, there is a lack of knowledge on the operation of the systems, especially among low-income households, which highlights the importance of implementing educational and supportive programs to promote long-lasting utilisation. The study points to other key challenges in South Africa's renewable energy policies, for instance, the absence of feed-in tariffs and incentives, which makes adoption less attractive. The study identified some solar PV risks, such as theft, implying that security measures should be included in solar transition discussions. Overall, this study offers insights for decision-makers and renewable energy stakeholders about the importance of meeting the various needs of different income groups, improving education on solar PV, as well as improving the policy environment to boost the adoption of renewable energy in South Africa.

CHAPTER 5: BARRIERS TO SOLAR PV ADOPTION IN SOUTH AFRICA: PERSPECTIVES OF KEY INFORMANTS

NOTE: *This chapter is written as a draft scientific paper that is ready for submission to a suitable scientific journal.*

Abstract

Globally, climate change threats have necessitated the shift to renewable energy options such as solar photovoltaic (PV). In South Africa, solar PV contributes approximately 5% to the total energy mix since the country relies heavily on conventional energy sources, predominantly coal. Within the South African household sector, solar PV adoption remains low, though a steady growth has been reported in recent years. Generally, the slow solar PV market penetration among South African households has been attributed to various financial, institutional, technical, and social barriers. These barriers have been studied from the household user perspective, yet an exploration of the barriers from the key informants' perspective, such as installers, distributors, manufacturers, and regulatory boards, can offer a better understanding that can be used to develop effective solar PV adoption interventions. Using in-depth interviews with key informants from across South Africa, the study examined their perceptions of barriers to household solar PV adoption. Important barriers reported include limited knowledge of solar PV, restrictive and inconsistent policies, and insufficient financial support. The study recommends that solar PV stakeholders need to invest in educating households on solar PV systems, in particular the behavioural interventions on energy consumption. The study also recommends for a liberalisation of the energy market to allow private companies to generate and distribute energy, as well as the standardisation of renewable energy policies across different provinces to assume uniform rates of adoption.

Keywords: Key informants, solar photovoltaic, renewable energy, uptake, barriers.

5.1. Introduction

Against a backdrop of climate change threats linked to increased carbon emissions, solar PV systems have a huge potential to develop a globally sustainable energy system (Ahmar et al., 2022; Magni et al., 2022). However, solar PV adoption can be constrained by various barriers, which is likely to explain its slow global uptake (Ahmed et al., 2022; Raymond et al., 2022). Thus, a nuanced understanding of barriers to the adoption of new technologies, such as solar

PV, is essential for designing interventions for rapid uptake of renewable energy sources (IEA, 2020). Several studies, including this study (see chapter 3 and 4), have focused on barriers to solar PV adoption from a user perspective (Dutt, 2020; Adwek et al., 2020), and discussions seem to revolve around barriers such as financial, technical, social, personal and institutional obstacles (Sæle and Cherry; 2017; Adwek et al., 2020; Amit et al., 2021). Financial barriers include the high capital investments required to buy solar PV systems and the lack of credit facilities that support the adoption of solar PV (Sæle and Cherry, 2017; Dutt, 2020; Adwek et al., 2020). For instance, a study in Kenya reported that most households could not afford the high capital investment needed to adopt solar PV (Adwek et al., 2020). Technical barriers are varied, including the unavailability of technical expertise and limited space needed for installing solar PV systems, particularly solar panels (Lo et al., 2018; Qureshi et al., 2017). For instance, technical barriers, which include the lack of skilled technicians to install the systems, were reported among Bangladesh households (Amit et al., 2021). Social barriers against solar PV adoption are mainly linked to security concerns, with potential adopters concerned about the theft of their systems (Raymond et al., 2022). For example, a study that was conducted in Pakistan found that most households in insecure neighbourhoods were reluctant to adopt solar PV systems due to theft (Qureshi et al., 2017). On the other hand, personal barriers, such as the non-availability of solar PV knowledge, have been reported in several studies (Dutt, 2020). For instance, a study conducted in India found that the lack of solar PV knowledge was one of the main reasons why India was lagging in household solar PV adoption despite its favourable climatic conditions for solar energy generation (Dutt, 2020). At the national level, institutional barriers, such as the non-availability of policies and regulations that support solar PV adoption, can also discourage potential households from adopting solar PV (Vasseur et al., 2013; Bermudez, 2018; Lo et al., 2018). For instance, Japanese households face difficulties in feeding back excess energy to the grid as monopolistic companies responsible for energy generation prioritise traditional forms of energy generation (Bermudez, 2018).

A key informant is defined as an expert source of information (Marshall, 1996). Insights on solar PV adoption from key informants such as policymakers and installers could provide valuable information that can be used to stimulate adoption (Diaz et al., 2017; Maqbool et al., 2020; Shari et al., 2023). Studies on insights from key solar PV informants such as policymakers, financiers, distributors, and engineers are few, yet such stakeholders can provide a different and nuanced understanding of the institutional, technical, and policy barriers that households may not identify (Qudrat-Ullah et al., 2020). For example, key informants might be more knowledgeable about the broader challenges that constrain market penetration of solar PV, such as regulatory inconsistencies, capacity limitations, and the need for feasible financing structures. Further, key informants can help to link household concerns to solutions through strategies that may otherwise not be immediately obvious to those who do not work within the field (Shari et al., 2023). Literature suggests that key informants understand solar PV technical and policy-related aspects and view barriers through a macro-lens (e.g., market dynamics, regulatory frameworks), whereas households focus on personal experiences and immediate concerns such as the high capital costs of solar PV installation (Rai et al., 2016). Literature also suggests that key informants are more informed about renewable energy policy framework and regulatory challenges, whereas most households are unaware of available policies and mostly rely on local information sources rather than formal policy communications (Wüstenhagen et al., 2007). Moreover, they can aid our understanding of the complex nature of energy transitions, which provides rich qualitative perspectives that can inform effective transition strategies (Qudrat-Ullah et al., 2020). Therefore, drawing on and incorporating the insights of key solar PV informants could advance our understanding of the barriers needed for designing interventions for encouraging rapid adoption.

Globally, insights from key informants on energy transitions are recognised in policymaking (Fischer et al., 2014; National Policy Development Framework, 2020). For instance, key informants play a very crucial role in informing, improving, and co-creating policy, where they are involved in policy discussions and policy debates (Fischer et al., 2014; National Policy Development Framework, 2020), which has been linked to effective decisions (Christensen et al., 2022). Further, key informants are not only instrumental in policy formulation but can also provide useful critiques of existing policies. For instance, in Germany and Australia, key informants have criticised energy policies for homogeneity and lacking context in the sense that they do not consider social class and location (rural or urban), which slows down the adoption of solar PV in rural areas (Schultea et al., 2022). Similarly, key informants in the United Kingdom (UK) have criticised renewable energy policies for homogeneity and suggested that policies need to prioritise marginalised rural areas by minimising the cost of rural adoption (Sovacool et al., 2022). In South Africa, key informants play a crucial role in the establishment of South Africa’s renewable policies, such as the Integrated Resource Plan (IRP) (National Policy Development Framework, 2020). The contribution of key informants in the energy sector is crucial in identifying the country’s energy needs, barriers, and the necessary steps needed to facilitate transitions to renewable energy sources such as solar PV (National

Policy Development Framework, 2020). Key informants help to assess the feasibility of policies that may contribute to the low and slow assimilation of solar PV among households. For example, key informants have described South Africa’s transition to solar PV as chaotic and quite dispersed (Groenendaal, 2023). For instance, there is no recorded information that documents all households that have adopted solar PV systems, making it difficult to regulate (Groenendaal, 2023). Moreover, key informants have criticised the Department of Energy's policies for favouring Eskom's monopoly over energy generation and distribution, disadvantaging potential renewable energy producers (Bridle et al., 2022; Mordor Intelligence, 2022). Key informants describe Eskom’s monopoly as an arrangement put in place by the government to consolidate its tax base as well as to avoid potential loss on current coal-tied benefits (Bridle et al., 2022). Further, key informants have also noted inconsistencies in policy implementation; for example, the Department of Energy continues to promote conventional energy sources at the expense of renewable energy, which contrasts with the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) goals of promoting renewable energy.

However, despite the significant role played by key informants in South Africa's energy sector, there are limited comprehensive studies aimed at assessing their views regarding solar PV adoption barriers among households. Current knowledge on solar PV adoption is mainly from household end-users, leaving key informants' perceptions largely unexplored, which may constrain the designing of interventions for encouraging rapid uptake of solar PV without ‘leaving anyone behind’. Further, though there are useful insights on key informants’ perspectives on barriers elsewhere, no holistic study on barriers has been done in South Africa despite its unique social, economic, and political contexts, including high levels of inequality, unstable economic and political conditions, and the influence of monopoly capital. Given South Africa’s drive to increase solar PV adoption, this study examined key informants’ perspectives on solar PV adoption barriers among households. The research was guided by the following research questions: (i) What do key informants identify as the key barriers to solar PV adoption among South African households? and (ii) what do key informants perceive as actions needed to enable rapid adoption of solar PV among South African households?

5.2. Methods

5.2.1 Data collection

The study employed an inductive approach to generate an in-depth understanding of the barriers to household solar PV energy adoption in South Africa. In inductive approaches, interviewers gather participants' views through purposeful in-depth conversations (Denzin and Lincoln, 1998). Data collection for this research was carried out between November 2022 and May 2024 and involved interviews with key informants in the energy industry as well as solar PV stakeholders in South Africa. Interviews were conducted via telephone, email, or in person, depending on the respondents' choices, mostly determined by availability and location. Key informants who participated in the study were identified through purposive and snowball sampling, which involved identifying participants who best served the purpose of the study and who, upon being approached, suggested other key informants to be interviewed. Participants were initially identified through company websites, and where a positive response was attained, a referral was asked, and the next potential respondents were approached for interviews. Key informants responded to a series of both open-ended and closed-ended questions with predetermined questions following Hansen and Świderska (2023). Key informants in the solar PV industry, including installers, distributors, retailers, manufacturers, academics, financers, and regulatory boards, were approached for their perspectives on barriers to solar PV penetration among households.

Twenty-five key informants were initially targeted for the interviews, but 17 responded positively based on their availability and willingness to participate (Table 5.1). The final sample size aligns with recommendations by Muellmann et al. (2021) and Francis et al. (2010), who suggest that 12-17 qualitative key informants' interviews are sufficient to reach data saturation. Besides, the inductive approach adopted in this study allowed for detailed discussions with key informants to generate data that can be used to make meaningful conclusions. Once identified, the key informants received an email with a consent form explaining the purpose of the research, the nature of their involvement, and the anonymity and confidentiality of responses, among other ethical considerations. Before conducting the interviews, ethical approval was obtained from the Rhodes University Ethics Committee (Review reference number 2022-5895-7199). Interviews were conducted during weekdays between 8 am and 5 pm and each interview lasted for a minimum of one hour. The interviews were conducted in English as all participants preferred it. In-person interviews were held in a quiet setting to minimise distractions, and with the interviewee's permission, a recording device was used, and only brief notes were taken on the script to maintain eye contact. Questions were asked one at a time to avoid overwhelming the respondents as well as to give them time to think. The interviewers remained neutral by trying not to show strong emotional reactions to responses following Jacob and Furgerson (2012).

Table 5.1. Distribution of key informants' respondents in the household solar PV adoption barriers study.

Position	Field of specialisation	Number of participants
Human resources Corporate specialist Technician	Energy production and distribution (Eskom)	3
Energy manager Town planner	Local governance	2
Researchers	Academia	2
Finance executive Directors Electrical contractors	Solar distributors and retailers	5
Technical managers	Regulatory board	2
Managers	Financing sector	3

The questionnaire was divided into three sections (See Appendix 5.1). The first section captured data on the respondents' profiles, including the company name, the field of the key informant, and their position in the company. The second section asked key informants to share their views on barriers to household solar PV adoption, their views on the actions needed to enable a rapid transition to solar PV in South Africa, and the constraints this may face. One of the questions asked in this section included, *"In your opinion, do you think that government policies have an influence on the transition to solar PV among South African households?"* The key informants were also asked to share their opinions on potential interventions needed to support the rapid uptake of solar PV by households.

5.2.2. Data analyses

Data were transcribed and recorded in an Excel spreadsheet. A thematic analysis was then conducted to extract key insights following Braun and Clarke's (2006) method. The process involved data familiarisation and the generation of initial codes from the data. These codes were then organised into potential themes. In the next stage, themes were reviewed and refined, and, where necessary, overly broad themes were divided into more specific ones. Finally, the themes were named and defined to accurately capture their essence. Direct quotes were used where appropriate to support and substantiate claims, as well as to provide clear examples of context and meaning, following Lingard (2019).

One of the main limitations of the study was that perceptions of key respondents do not represent the collective views of all key informants in South Africa. Another limitation points to the use of snowball sampling for data collection, particularly its use of referrals for data collection. This may lead to overrepresentation of certain groups or viewpoints, resulting in a sample that may not represent the broader population. Consequently, it is not possible to generalise the findings, but valuable insights from experts' opinions on barriers to household solar PV adoption can be gleaned.

5.3. Results

5.3.1. Perceived barriers to solar PV adoption

Knowledge barriers

Concerning the availability of knowledge for solar PV adoption among households, a substantial number (12) of key informants reported that households had insufficient technical knowledge of solar PV systems (Table 5.2). For example, one key informant stated that,

> *"Most households are not informed about solar PV capacity. One thing that households need to be aware of is they cannot be 100% off-grid for appliances with elements that require more energy. Big appliances limit battery life".*

Some (5) felt that solar PV technology was still relatively new and continuously evolving to the extent that most households could not catch up. For instance, one key informant reported that,

> *"Products are also evolving very quickly, making staying up to date very difficult; the moment households are trying to learn a new product, the industry introduces another one, which makes it difficult for many households to follow".*

To address the knowledge barriers, 10 key informants suggested several educational interventions, including awareness campaigns, behavioural energy use interventions as well as solar pilot projects. For instance, one of the respondents stated that,

> *"There is a need for more educational initiatives across the country on what solar PV options are available. Community-based initiatives are more accessible to everyone, so*

this can be done in the form of awareness campaigns or open days facilitated by the government or non-governmental organisations".

Institutional barriers

Regarding the availability of supportive policies for household solar PV adoption, a significant number of key informants (16) indicated that South Africa lacks adequate policies to promote the adoption of solar PV systems (Table 5.2). They identified several factors contributing to this challenge, including Eskom's monopolistic practices and the constant changes in renewable energy policies, which hinder the integration of solar PV. One key informant highlighted this issue by stating that,

> *"Eskom is responsible for setting the regulations, although the regulations are very stupid especially with regards to the types of inverters one can use to feed back to the grid. The type of inverters they need to allow someone to feed back into the grid is three times more expensive than the inverters that most people have".*

Some key informants (5) also reported that the country had renewable energy policies, but these policies keep on changing from time to time and thus do not give confidence to households. For example, one of the key informants mentioned that,

> *"The issue of feeding back to the grid is a whole different issue altogether, and it keeps on changing. If you want to feed back to the grid, you need to have a specific type of inverter. At first, all inverters were allowed to feed back to the grid, but this was later changed, yet households had bought these inverters already".*

Other respondents (10) confirmed the availability of supportive renewable energy policies; they reported that these policies differed from province to province, and their contribution to solar PV adoption was very minimal. For example, one key informant responded that,

> "*South Africa has renewable energy policies. However, they differ from province to province and municipality to municipality. For example, Greater Kokstad has policies that are very different from Makana municipality policies. Greater Kokstad has policies that support transitions through its Greater Kokstad Integrated Sustainable Development plan; if we look at provinces, only the Western Cape province in South Africa has fully activated the Municipal Feed-in Tariffs to incentivise households to feed back to the grid.*

To address institutional barriers, several recommendations, including the standardisation of renewable energy policies across provinces and the liberalisation of the energy market, were suggested by 10 key informants (Table 5.2). For instance, one of the key informants reported that,

> *"The electricity market needs to be liberalised. For example, the country needs to move towards a deregulated or competitive electricity market by first unbundling Eskom. It should only be responsible for the transmission system. Otherwise, households should not even know that it exists".*

Similarly, another key informant reported that,

> *"In the Western Cape province, households that can produce surplus can now sell back to the grid, given that they meet the requirements. Only if these policies were adopted by other provinces, the country would have been on a different adoption level".*

Table 5.2. Perceived barriers (number of respondents) to solar PV adoption.

Barrier	Responses	Recommendations
Knowledge barriers (12)	• Household energy users do not know the technical processes involved in solar PV generation. *(7 respondents).* • Solar PV technology is still new, and it is evolving so fast that users cannot catch up. *(5 respondents).* • No effort from the responsible stakeholders to disseminate information on solar PV, such as awareness campaigns. *(10 respondents).*	• Educational campaigns, open days aimed at preparing households before adoption. *(10 respondents).* • Behavioural energy use interventions (educating household on which appliances to use during the day and at night). *(5 respondents).* • Solar pilot exercises aimed at giving households an experience before they commit to purchasing their own systems. *(1 participant).*
Institutional barriers (16)	• Lack of uniformity in renewable energy policies across municipalities and provinces; for example, Western Cape has Feed-in Tariffs, whereas other	• Standardisation of renewable energy policies across provinces *(10 respondents).* • Consistent policies over time, and the government to compensate for any expenses

	provinces do not. *(10 respondents).* • Constant changes in renewable energy policies, causing uncertainties among households. *(7 respondents).* • Eskom's monopolistic policies are slowing down the rate of adoption. *(9 respondents).*	incurred by households as a result of policy changes. *(7 respondents).* • Liberalisation of the energy market to allow other players to feed to the grid. *(9 respondents).*
Financial barriers (15)	• Insufficient financial support to cover the capital investment needed for adoption *(15 respondents).* • Banks are charging exorbitant interests on solar PV loans. *(13 respondents).*	• Banks to offer better financing options with reasonable interest rates. *(15 respondents).* • The government can invest in mini-grids to address the issue of prohibitive start-up costs. *(3 respondents).*

Financial barriers

When key informants were asked on whether there are any financing options for solar PV among households, most respondents (15) confirmed that there are supportive financial arrangements, but they were not sufficient to cover the high start-up cost of solar PV systems. For instance, one responded that,

> *"As it stands, with the current subsidies and financial assistance offered by banks, adopting solar PV is still very expensive. For now, it is important for your average household to rather be looking at loadshedding combating option rather than full off-grid options as the capital outlay means that you over capitalise on your property and the present costs".*

Similar responses were echoed by other key informants, for example another one reported that,

> *"Subsidies are there, but they only cover 25% of the cost of solar panel. On the other hand, banks are charging unbelievable interests for on solar PV loans".*

5.4. Discussions and implications

Knowledge barriers

Results from this study demonstrate that most key informants perceived that households lacked the knowledge needed to adopt and effectively use solar PV. This underscores the reality of knowledge barriers in the adoption of solar PV among South African households. For instance, key informants such as solar PV installers and distributors engage with households on a regular basis and provide direct insights into the challenges that most households face. Key informants' insights demonstrate that while households may be willing to transition to solar PV systems, they often do so without a proper understanding of the technology and how to get the best out of it. Households are quick to purchase solar PV systems without a proper understanding of the capacity of the systems they are installing, which in most cases leads to unrealistic expectations, disappointments, and potential damage to the system, as was reported by Thobejane et al. (2019), in a study conducted with beneficiaries of the government Solar Water Heating programme in South Africa. A recent study in India found that inadequate levels of solar PV knowledge among solar PV households led to low adoption, improper use of solar PV systems, and negative perceptions among households (Dutt, 2020). This calls for educational campaigns aimed at equipping households with the required knowledge which can prepare them for adoption. Islam and Meade (2013) suggest that people are reluctant to adopt solar PV technologies if they are uncertain and lack enough information about them. A study conducted in Pakistan found that households with enough knowledge on the renewable products they wanted to purchase were better positioned to make informed decisions pertaining to the size and quality of the systems that best suited their energy requirements than those without knowledge (Malik et al., 2020). While there is an alignment between perceptions of key informants and those of households pertaining to the lack of knowledge, insights from key informants further suggests households' knowledge is rather basic. For example, it does not always cover aspects such as battery capacity, balancing behaviour and energy needs, and other complex technical dimensions.

Altogether, this highlights the need for interventions such as educating households on which appliances they can use during the day when solar PV generation is higher and which ones they can avoid using at night when generation is lower. In addition to the household perspectives, key informants further demonstrate the impact of information overload, resulting from the continuously evolving solar PV technologies resulting in confusion and misinformation. This calls for solar PV manufacturers to develop platforms and apps that allow households to easily compare solar PV systems and provide the latest updates on solar PV systems when households need them. Marketers and distribution companies can also conduct solar PV pilot exercises, where they can set up solar PV systems where households can learn and gain experience before they decide to invest in their own systems. Solar PV pilot projects have been implemented in the Folovodwe village, South Africa, where the government conducted a solar trial by donating solar PV systems to selected households (Bikam and Mulaudzi, 2006). This project significantly boosted local knowledge about solar PV energy, equipping the community with a better understanding of how solar PV systems work (Bikam and Mulaudzi, 2006).

Solar PV knowledge can also be administered through awareness campaigns, open days, community-based workshops, and seminars, which can equip households with basic principles such as the benefits, installation requirements, and maintenance requirements for solar PV systems. In developed countries such as the United States, the American Solar Energy Society organises national solar tours where they showcase households and buildings with solar PV installations, presenting households with the opportunity to learn about solar PV energy, including effective and efficient use in their own homes (American Solar Energy Society, 2024). Similar initiatives can be implemented in South Africa, where households can get an opportunity to have hands-on experience with the systems before they even decide to install them. A key result from this study is that solar PV information dissemination should go beyond just providing basic information about solar PV to households but such information should include technical system-related information that can help households buy solar systems that give them a satisfactory transition from non-renewable to renewable energy.

Institutional barriers

The findings of this study indicate that South Africa has insufficient policies that can encourage rapid solar PV penetration among households. Eskom's monopoly in the energy industry comes with persistent challenges for the assimilation of renewable energy as the company mainly depends on coal-fired generation plants and has an influence on private sector participation in the energy industry (Eskom, 2019; 2020). Through the Electricity Regulation Act (2006) which declares Eskom as the primary energy supplier, the company is responsible for implementing how renewable energy sources are managed (National Policy Development Framework, 2020). Moreover, through the REIPPP, Eskom controls all energy purchases from independent power producers, giving it influence over feed in tariffs indirectly (Bridle et al., 2022; Mordor Intelligence, 2022). Moreover, through the Electricity Regulation Act (2006), Eskom is responsible for approving the paperwork required for households to feed back to the grid (Department of Energy, 2019) and, thus, may deliberately delay the process (Baker and Phillips, 2019). For instance, the city of Cape Town has a backlog of applications to feed back into the grid, with households waiting for a long period of time before getting approval to sell back to the grid (Baker and Phillips, 2019; City of Cape Town, 2022). These delays can discourage households from adopting solar PV, particularly those whose main motivational drivers are largely economic (i.e., to cut costs and recoup their investment in solar PV from grid supply). Thus, there is a need for a liberalisation of the energy industry in South Africa, where private companies are also given the responsibility of energy generation. A liberalised energy market would also mean that municipalities are not responsible for the electricity supply (Prete et al., 2019; Morrison, 2022). Private companies will operate the distribution systems and retailers will sell or buy energy to and from potential prosumers.

Market liberalisation has been implemented with success in the UK and US energy markets (Morrison, 2022). For instance, the UK energy market liberalisation initiative, although not specifically targeted at solar PV adoption, created a conducive environment that fostered competition and incentivised renewable energy options (Solar Energy UK, 2021). Consequently, since the liberalisation of the UK energy market, solar PV has increased, with capacity doubling to 13.5 GW by 2021 (Solar Energy UK, 2021). Furthermore, projections indicate a continued increase, with capacity expected to reach 30GW by 2030 (Solar Energy UK, 2021). A liberalised energy industry would also mean that there are fewer bureaucratic processes involved when household energy producers try to access the energy market (Solar Energy UK, 2021). However, in South Africa, energy market liberalisation might face several challenges to its implementation. Firstly, Eskom's monopoly in the energy industry makes it very difficult for new players to contribute to the energy market. Eskom is in a financial crisis, and thus, allowing new players in the industry will compromise its already critical financial state. Secondly, there is no political will to liberalise the energy market as it may result in massive job losses with a terrible impact on the government.

These results also suggest there are variations in solar PV policies among South African provinces, implying that the rate of solar PV adoption also varies across the country. For instance, while the Gauteng province has the largest installed rooftop solar PV capacity in South Africa, the Western Cape province has experienced the fastest growth between 2023 and 2024, tripling its capacity, mainly because of its feed-in policies (Eskom, 2024). Studies by Akinbami et al. (2021) and CMEN (2024) report that South Africa lacks consistency in policy effectiveness across different regions, which could hinder uniform adoption rates and overall progress towards renewable energy goals. South Africa is a federal state that has distinct policy administrations that allow a degree of autonomy for individual regions and provinces to implement policies designed to meet their specific needs (Mhlongo, 2020). Though this type of governance empowers provinces, it can also be a barrier to the smooth administration of solar PV. Without a unified policy environment and consistent incentives, solar PV adoption may be fragmented, resulting in suboptimal outcomes. For instance, the Ndlambe municipality in the Eastern Cape province has implemented policies that impose higher rates on solar PV adopters compared to non-adopters, a measure that could potentially deter prospective solar PV adopters within the municipality (Ratepayers Revolt, 2024). Studies suggest that the absence of standardised policies diminishes their potential impact (Chidembo et al., 2022b; McKay and Hendricks, 2022). For example, in the absence of standardised policies, households face conflicting information about government tariffs, incentives, and regulations which might deter potential adopters who may find it difficult to navigate through an inconsistent policy environment (Mhlongo, 2020; Chidembo et al., 2022b).

Further, policy disparities across provinces can result in unequal access to solar PV benefits, with households in some provinces enjoying more subsidies, net metering programs, and solar rebates while others do not. Thus, to gain the confidence of households, there is a need for standardisation of renewable energy policies across provinces, where the government and regulatory bodies collaborate in creating uniform guidelines and regulations which guide the development and deployment of renewable energy sources such as solar PV. The goal of standardisation is to harmonise policies across different provinces in the country to ensure consistent, equal, and efficient adoption of renewable energy (United States Environmental Protection Agency, 2024). This can be done by establishing a national framework that can guide all municipalities with acceptable renewable energy policies. For example, the United States has Renewable Portfolio Standards (RPS) that set overall goals while allowing individual states to create local regulations if they align with the RPS objectives (United States Environmental Protection Agency, 2024).

Key informants also reported on the constant changes in renewable energy policies, which cause uncertainties among solar PV prosumers. For instance, initially, in the city of Cape Town, all households producing excess solar PV energy could feed back to the grid for credits. However, the city introduced more stringent policies which excluded many households. For instance, they now require specific bi-directional meters, which cost more than ZAR12 000.00 (US$625), whereas the feed-in rate is as low as ZAR0.79/kWh as approved by the National Energy Regulator of South Africa (Githahu, 2023; News24, 2023). Thus, selling power to the national grid can be expensive and challenging, in part due to the costs of electrical engineering and CAD designer services, the costs of a bi-directional meter, and a monthly fee for the bi-directional meter as it is provided by the municipality. This means that although the payback period (the time it takes to earn on solar PV systems) is reasonably short (4-6 years) in South Africa due to high energy costs, revenues from selling excess solar-generated power to the grid are very insignificant, hypothetically taking more than 25 years to recoup the cost (R12 000) of a bi-directional meter if an excess of solar power 1 kWh per day is sold to the grid. Thus, feeding back to the grid was not economically feasible for most households whose motivation is to sell excess energy to the grid. Moreover, households are now required to register with the Small-Scale Embedded Generation (SSEG) programme and pay operational tariffs to feed energy back into the grid (Eskom, 2024). These constant policy change barriers have a potential impact on the country's transition to solar PV as households will not invest in solar systems due to future policy uncertainties. Uncertainties emanating from sudden changes in policies have also been reported in Spain. For instance, the country suddenly slashed all feed-in tariffs, which affected many prosumers and small-scale power producers (Castro-Rodríguez and Miles-Touya, 2023). Thus, to build trust with households, policies should be consistent and if changes are necessary, households should be compensated for any additional costs they incur. The results of this study highlight the valuable insights from key informants regarding the transition to solar PV adoption. While policy barriers have been reported, particularly by high-income households, key informants provide a deeper understanding of these issues. Specifically, their insights reveal not only the impact of current renewable energy policies on solar PV adoption but also how variations in policies across different provinces influence this process. Additionally, key informants' perspectives contrast with those of low-income households (see Chapter 3), a significant proportion of whom reported that the government is very supportive of solar PV. This support may be attributed, in part, to government donations of solar water heating systems received by some low-income households.

Financial barriers

Despite the availability of financing options and subsidies to adopt solar PV, key informants noted that adoption among households is still affected by high start-up costs, which implies that the several financing options available for households are still insufficient to stimulate adoption. These results are consistent with findings by Sæle and Cherry (2017) and IEA (2018) among Norwegian households, which reported that households still considered solar PV expensive, despite receiving up to 30% in subsidies from the government. Our findings on household perceptions (see Chapter 3) also highlight issues relating to high capital costs for solar PV investments as one of the common barriers to solar PV adoption among South African households. To address issues of prohibitive costs, most key informants think that banks need to offer better financing options with reasonable interest rates to make solar PV more accessible. Major banks in South Africa, such as Standard Bank, Nedbank, and Discovery Bank, have started offering loans for solar PV adoption. For instance, Standard Bank has initiated a "bounce-back loan guarantee scheme that offers up to ZAR 300 000 (approximately $16 000 using the 2024 exchange rate) for solar PV investments. Similarly, Nedbank, through its Avo Solar scheme, now offers competitive renewable energy packages, whereas Discovery Bank has partnered with Rubicon to provide solar PV investment loans (Property Review, 2024). However, most South African households cannot qualify for these loans as they might not have collateral or are debt-ridden (Kereeditse and Mpundu, 2021). Moreover, solar PV loans seem to have slightly higher interest rates compared to other loans, for example, Standard Bank offers solar PV loans with interest rates capped at prime +2.5% compared to home loans with interest ranging around prime -0.5% to prime +1%, depending on the customer (Standard Bank, 2023).

Another way to address issues linked to start-up and operational costs is for the government to consider investing in mini-grid systems, which would relieve households from installation costs as well as navigate the technical complexities of solar PV operation. Evidence suggests that mini-grids are the most cost effective than stand-alone solar PV systems because investments and operational costs are shared (World Bank, 2019; UNDP, 2020). These strategies could significantly ease the burden on households and promote broader adoption of renewable energy by removing administrative costs related to individual selling of excess solar PV energy to the grid, cost of engineering services, and safety issues. Apart from the identified barriers and recommendations from this study, there are several recommendations that can help to alleviate barriers to solar PV adoption among South African households. To increase the contribution of solar PV into the energy mix, the government and regulators need to allow the use of cheaper inverters to feed back into the grid, if they meet the required safety standards. Initially, all inverters, including cheaper ones, were permitted to feed back to the grid, but the policy changed after households had already purchased these systems, which led to unnecessary costs for homeowners (News24, 2023; Githahu, 2023). These strategies would significantly ease the burden on households and promote broader adoption of renewable energy.

5.5. Conclusions

In conclusion, views from key informants underscore the important role of solar PV knowledge, renewable energy policies, and financial institutions in influencing solar PV adoption among South African households. In particular, the study shows differences in understanding of the knowledge barriers between households and key informants. While households felt they were aware, their knowledge was limited to a basic understanding of solar PV, such as its conversion of sunlight into energy, but they did not highlight aspects related to the balance between energy use behaviour and generation capacity, optimisation of use during the day and issues to do with storage complexities. While there are similarities between key informants and households pertaining to the lack of solar PV knowledge as a barrier to adoption, insights from key informants show differences in understanding of key aspects including the mismatch between solar PV system capacities and household expectations, as well as the confusion caused by continuously evolving solar PV technologies. Although institutional barriers were highlighted by households (see Chapter 4), most key informants emphasised policy inconsistencies, especially differences in policy framing and implementation between provinces. The complexity of South Africa's renewable energy policies, particularly on disparities across provinces, is partly due to the country's governing structures. South Africa needs to revisit its solar PV policies and improve on alignment between national and provincial policies. The study has also highlighted financial barriers that require financial institutions to be involved in promoting solar PV adoption. Overall, most key informants recommended the development of educational programmes to enhance solar PV information dissemination, standardised renewable energy policies across provinces, and improved financial support mechanisms such as low-interest loans and mini-grid systems.

CHAPTER 6: SYNTHESIS OF FINDINGS AND POLICY IMPLICATIONS

6.1. Main conclusions and key implications

The broader objectives of the thesis were to examine the barriers to solar PV adoption among South African households as a basis for developing recommendations that could assist in achieving a just transition to renewable energy, for which solar PV is one of them. This was achieved through conducting four studies whose key questions were (i) what is the research progress and conceptual insights on barriers and enablers of solar PV adoption in South Africa? (ii) what are the barriers to solar PV adoption among urban households in the Eastern Cape province of South Africa? (iii) what are the primary motivations and experiences of solar PV adoption among South African households? and (iv) what are the key informants' views on barriers to solar PV uptake by households? The general conclusions and key recommendations for each of the above-mentioned research questions are detailed below.

Chapter 2 identified several key implications for the country's attainment of energy security and the achievement of environmental goals. Despite the significant benefits of solar PV among households, its adoption is still very low pointing to numerous barriers - financial, institutional, technical, and social which hinder its adoption. The high capital investment of solar PV systems makes them inaccessible to most South African households, especially those in the low-income category. This also implies that low-income households are excluded from government incentives such as the 25% solar rebate because they do not have the means to pay for installations upfront or qualify for loans, and thus, they remain dependent on unreliable conventional energy sources. Lack of access to knowledge on solar PV implies that households do not have information on the benefits and incentives of solar PV, which may lead to uncertainty about the system. The presence of social barriers such as theft implies that most households, especially those located in secluded and high crime rate areas, may be willing to adopt solar PV but might be prohibited by the fear of losing the systems due to thievery. The non-availability of institutional support implies that there are no clear guidelines for solar PV adoption. This may result in a disorganised transition where some groups (e.g., high-income households) benefit from the transitions whilst the low-income households are left behind. In general, barriers to solar PV have a disproportional impact on low-income households, implying that addressing these barriers requires tailored interventions. Additionally, addressing these barriers requires a collective effort among different stakeholders, including the government, private sectors, and civil society, to ensure that all solar PV initiatives are inclusive. To address these barriers, the study recommends the following:

- Financial interventions in the form of low-interest loans, solar leasing programs, and feed-in tariffs that can expand solar PV accessibility for diverse households, especially helping low-income families overcome barriers to energy access. These measures can help to overcome the start-up costs for solar PV adoption.
- Targeted awareness campaigns such as community workshops can help to reduce cognitive barriers, especially among low-income households.
- To reduce the upfront and maintenance costs, the government can train technicians who can work with Eskom/municipalities rather than operating privately. Installation of solar PV systems, to come with installation and maintenance arrangements at no additional cost for the duration of the system's warranty.

Chapter 3 highlighted that solar PV barriers affect low-income households disproportionately. This implies that though barriers affect both high- and low-income households, low-income households are more affected because of their lack of knowledge and limited access to financial incentives. Furthermore, this lack of awareness among low-income households might make socioeconomic differences worse because they are less likely to trust or invest in renewable energy sources. From an institutional lens, this chapter demonstrates that, though the country has renewable energy policies, they are not inclusive and cannot motivate the adoption of solar PV across all income groups. Lack of inclusivity can hinder accessibility for low-income households, resulting in a segmented renewable energy landscape where solar PV adoption remains an initiative for affluent households. This gap does not only have an impact on universal access to affordable clean energy, but it also reflects a missed opportunity to address energy poverty in the country and just transition. The chapter also demonstrates that there is limited knowledge of solar PV among households, implying that households, especially the low-income, may not be aware of the possible long-term cost savings, reliability as well as environmental benefits of solar PV adoption, which can impede the adoption of solar PV. To address these barriers, the study recommends the following:

- Awareness campaigns and educational programmes aimed at equipping households with solar PV knowledge (see recommendations for Chapter 2 above).
- Financial interventions that can assist in the adoption of solar PV (see recommendations for Chapter 2 above).

- Inclusive transition frameworks which can promote an energy transition narrative that prioritises energy security alongside environmental sustainability. Targeted policies are important in ensuring that low-income households are not excluded from the renewable energy transition.

In Chapter 4, the experiences of solar PV users have several key implications for the future of solar PV adoption among South African households. Differences between motivational drivers of high-income and low-income households highlight the importance of targeted interventions addressing the unique challenges faced by each group. For instance, high-income households highlighted that they were driven by the need for convenience to adopt solar PV, implying that interventions directed towards high-income households need to emphasise the importance of solar PV as a reliable source of energy. On the other hand, for low-income households who are mostly dependent on government donations because of their limited financial resources, interventions should be centralised around the cost-saving potential of solar PV systems. In addition, the role played by social influence on solar PV adoption implies that community-based initiatives could accelerate solar PV adoption. To address the solar PV knowledge gap, comprehensive educational and support programs need to be integrated into solar PV initiatives, ensuring that users can maximise the efficiency and lifespan of their systems. In addressing the barriers mentioned in this chapter, the study recommends the following:

- Targeted interventions to cater to the unique needs of different income groups, for example, providing low-interest loans, subsidies, and solar leasing programs specifically designed to make solar PV systems more accessible to low-income households (see recommendations for Chapters 2 and 3).
- Establish local solar PV co-operatives or neighborhood groups to foster collaboration, share experiences, and create a supportive network for new users. Such initiatives could also reduce costs through bulk purchases and shared maintenance services.
- Renewable energy debates need to be centralised around what people consider important (i.e., convenience).

Chapter 5 shows that there is a gap in in-depth knowledge of solar PV technology at the household level, which can limit its effective use and, thus, create unrealistic expectations about the capacity that the systems can support, consequently slowing the adoption process. The study demonstrates the importance of enhanced educational initiatives in providing households with the necessary insights into efficient solar PV usage, system maintenance, and storage management. Findings also demonstrate that households are also subjected to technology overload as technology keeps evolving so fast, implying that people cannot catch up. Furthermore, the study highlights the role of inconsistent renewable energy policies across provinces and the challenges they create for households and suppliers alike. Findings from the study also imply that standardised renewable energy policies across provinces are essential to simplifying the adoption process, thus reducing operational barriers and creating a supportive environment imperative for a more robust adoption among households. Results from this chapter also imply that monopolistic policies in South Africa's energy sector restrict the participation of alternative players, such as households, in contributing to energy generation. This concentration of control slows the adoption of decentralised energy sources, limiting the growth of renewable energy. Further, the variability of renewable energy provinces has an impact on both households and suppliers. Lack of consistent, renewable policies may hinder the adoption process, leading to higher operational and financial obstacles. To address barriers mentioned by key informants, the study recommends the following:

- Financial interventions (see recommendations for Chapters 2,3 and 4).
- Open days, community-based workshops, and seminars that can equip households with basic principles such as the benefits, installation requirements, and maintenance requirements for solar PV systems.
- Behavioural energy use interventions, for instance, educating households on which appliances to use during the day and at night.
- There is a need for unified policy frameworks at the national level to simplify procedures like grid feed-in requirements to create a more supportive atmosphere for the adoption of renewable energy.
- Liberalisation of the energy industry in South Africa, where private companies are given the responsibility of energy generation. This can create competition among suppliers, leading to lower energy prices, increased innovation, and greater choice for consumers.
- Mini-grid systems may offer a flexible solution for communities not fully served by the main grid, enhancing energy independence and sustainability in remote areas.

In general, results from this work point to the need for a nuanced approach to South Africa’s renewable energy transition. While environmental sustainability is important, transition debates need to be framed within an energy security discourse for it to be more appealing to households.

6.2. Conceptual framework for understanding solar PV barriers and interventions

Drawing from the study findings, a conceptual framework (Table 6.1) that can meaningfully be used to describe and explain the various barriers to solar PV adoption among South African households is proposed. Understanding the barriers to solar PV adoption requires a distinction between recognisable and hidden barriers. We define recognisable barriers as the easily identifiable perceived and actual factors that can prevent the adoption of solar PV. In the literature, these tend to be understood from the perspective of non-adopters of solar PV and are often cited as the primary reasons for not adopting solar PV systems (Hendricks, 2016; Tlhatlha, 2020; McKay and Hendricks, 2022). These barriers include financial barriers, such as high start-up costs and limited access to affordable financing options, which remain a significant obstacle for many households in South Africa. They also include institutional barriers, such as the lack of an enabling policy environment that can incentivise households to supply excess solar PV energy to the grid, which could further slowdown the adoption process (see Chapter 4, sections 4.4.5). Recognisable barriers also include cognitive factors such as limited public awareness and preconceptions relating to the reliability of solar PV systems, especially during adverse weather conditions. Technical barriers include factors such as the fear of possible technical complications of the systems, thus causing hesitancy among households to invest in solar PV systems (Chapter 3, Section 3.3.3).

While recognisable barriers are critical, they do not include the full range of hidden barriers associated with solar PV adoption, especially the barriers faced by households after adopting the systems. Hidden barriers are defined as preconceptions/false expectations and negative experiences relating to solar PV systems functionality, which can constrain well-meaning solar PV initiatives from achieving optimum solar PV penetration. At a rudimentary level, these barriers sound like recognisable barriers (e.g., financial, technical, and policy barriers), but they tend to be more complex than visible barriers. These hidden barriers, which are often overlooked in the literature, are mostly faced by households and can significantly impact user satisfaction and the perception of solar PV systems among potential adopters. For instance, households that have invested in solar PV may later discover that many of their household appliances are incompatible with the solar PV systems, and thus, to continue using the systems, they might be required to acquire more efficient appliances, which is an expense that most households might not be prepared for. Another example of a hidden barrier that many solar PV adopters, especially those seeking to connect their systems to the national grid, usually face is system incompatibility with the grid infrastructure. This barrier emanates from the technical requirements needed to integrate solar PV systems to the grid. For instance, the need for specialised inverters that allow the synchronisation of the systems to the grid might not be considered at the time of purchase and beyond the reach of many households. Many households are unaware of these requirements during the initial purchase and installation process, often due to a lack of clear guidance or insufficient technical support from the installers and suppliers. In addition, the complications of navigating grid-connection requirements and the technical knowledge required to ensure compliance can be overwhelming for some households, especially those without prior experience or access to expert assistance. Hidden barriers not only affect the experience of current users but also create a negative image for potential adopters, as word-of-mouth experiences play a substantial role in influencing decisions. The complex interplay of recognisable and hidden barriers might result in low solar PV adoption, despite its potential for clean and green energy.

Although these barriers can be categorised as either recognisable or hidden barriers (Table 6.1), they still need to interrogated using socio-economic lenses such as an income gradient. This is because the socio-economic lenses (i) assist in identifying the types and impacts of barriers within each income group, (ii) assist in developing targeted interventions that are applicable to each socio-economic group, and (iii) assist in achieving the socially just transition to renewable energy. Although results from this study point to the fact that low-income households need help in transitioning to solar PV, the type of help goes beyond just financial assistance, but policy adjustments to favour solar PV adoption by less privileged members of society. In essence, interventions need to be skewed towards certain income groups (low-income) if solar PV adoption is to be increased. Therefore, any conceptual framework to understand solar PV barriers and interventions needs to be done within the confines of the socioeconomic structures of South African society. This could also be because South Africa has one of the most unequal societies in the world, mainly due to apartheid laws that segregated people according to race and class. Therefore, any technological adoption intervention needs to recognise socio-economic differences within South African society to make sure no one is left behind.

Table 6.1. Categorisation of barriers to solar PV adoption among households.

Type of barrier	Recognisable barriers	Hidden barriers
Financial	• High capital cost required for solar PV adoption • Lack of access to financing	Frustrations from: • Unexpected operational costs (e.g., changing appliances to more efficient ones)
Institutional	• No access to supply to the grid • Lack of comprehensive policies for supporting solar PV adoption	Frustrations from: • Eskom's monopoly as available policies support traditional energy providers over renewable energy sources • Lack of uniformity in solar PV policies across different provinces, resulting in unequal access to solar PV benefits • Constant changes in renewable energy policies resulting in uncertainty which discourage long-term investment in solar PV
Cognitive	• Lack of information on the functionality of solar PV systems (e.g., perceptions that solar PV systems do not generate sufficient energy during adverse weather conditions) • Lack of information on the available financial support for households	Negative experiences from: • Lack of information on energy-saving behaviours or system optimisation strategies under different weather and user conditions • Lack of knowledge regarding the alignment between solar PV capacity and household energy needs.
Technical	• Technical faults and non-availability of solar PV systems maintenance • Malfunction of solar PV systems • Unsuitable rooftops for solar PV installation	Negative experiences from: • Municipal energy distribution systems that are not designed to sell excess solar PV energy to the grid • Grid incompatibility issues, where the integration with the national grid often requires specialised inverters and technical compliance, which are not communicated upfront

6.3. Future perspectives

This study recognised the importance of visible and hidden barriers in providing a comprehensive perspective on the barriers affecting solar PV adoption among South African households. While recognisable barriers are frequently mentioned as the primary factors affecting solar PV adoption, the influence of hidden barriers cannot be underestimated. These hidden barriers do not only impact solar PV adopters, but also create negative perceptions that can discourage potential solar PV adopters. Thus, future research should understand both categories of barriers to creating effective interventions. A successful transition to solar PV may not be realised without due consideration of the hidden barriers. Addressing recognisable barriers can ensure that solar PV adoption becomes more accessible and appealing to households by reducing start-up costs, improving public awareness, and enhancing supportive policies. Similarly, addressing hidden barriers can ensure user satisfaction, build trust, and encourage the long-term sustainability of solar PV systems. Therefore, in order to create impactful interventions, a holistic approach targeting both categories of barriers is needed. Policy and energy stakeholders need to prioritise the development of uniform, consistent, and inclusive policy frameworks, provide financial support mechanisms, and enhance technical education and post-adoption support. Addressing a full spectrum of barriers can unlock the country's solar PV potential and can accelerate a just transition to renewable energy.

Future studies should also examine how interventions aimed at reducing solar PV adoption are effective and if they will result in increased adoption. For example, this study has suggested interventions such as awareness campaigns, financing solar PV in low-income areas, and amendment to solar PV policies. Some of these interventions are already being implemented yet their effectiveness is yet to be assessed. For example, the implementation of tax rebates by the South African government to stimulate solar PV adoption needs to be assessed for efficacy in terms of increasing the adoption rate. Lastly, this study was conducted in urban areas located in the Eastern Cape province of South Africa. Thus, more similar studies in other areas are needed to develop effective interventions based on varying contexts.

References

Abbass, K., Qasim, M.Z., Song, H., Murshed, M., Mahmood, H. and Younis, I. 2022. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29, pp. 42539-42559 doi.org/10.1007/s11356-022-19718-6.

Abdelrazik, S.E., Abdelaziz, Mariam F.H. and Tarek M.H. 2022. Climate action: Prospects of solar energy in Africa. *Energy Reports*, 8, pp. 11363-11377. doi: 10.1016/j.egyr.2022.08.252

Abrahamse, W. and Schuitema, G. 2020. Psychology and energy conservation: Contributions from theory and practice. *Energy and Behaviour*, 10, pp. 19-44. doi: 10.1016/B978-0-12-818567-4.00001-6.

Acheampong, A.O., Adebayo, T.S., Dzator, J. and Koomson, I. 2023. Income inequality and economic growth in BRICS: insights from non-parametric techniques. *The Journal of Economic Inequality,* 21, pp. 619-640. doi.org/10.1007/s10888-023-09567-9.

Adams, S.L. 2012. South African consumer attitudes towards domestic solar power systems [Masters Dissertation, University of Pretoria]. https://repository.up.ac.za/handle/2263/24826.

Adwek, G., Boxiong, S. and Ndolo, P.O. 2020. The solar energy access in Kenya: a review focusing on pay-as-you-go solar home system. *Environment Development Sustainability*, 22, pp. 3897-3938. doi.org/10.1007/s10668-019-00372-x.

Agaja, S.A, Ajibade, B.F, Nwaezeapu, A.O. and Igbinosun, A. 2020. Study on the performance of selected solar photovoltaic systems installed by government intervention agencies in Delta state, Nigeria. *International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences*, (8)5, pp. 81-87. doi: 10.5281/zenodo.4164353.

Ahmad, T., Hasan, Q. U., Malik, A. and Awan, N.S. 2015. Remote monitoring for solar photovoltaic systems in rural application Using GSM network. *International Journal of Emerging Electric Power Systems,* 16(5), pp. 413-419. doi: 10.1515/ijeeps-2015-0017.

Ahmar, M., Ali, F., Jiang, Y., Wang, Y. and Iqbal, K. 2022. Determinants of adoption and the type of solar PV technology adopted in rural Pakistan. *Frontiers in Environmental Sciences,* 10, 895622. doi: 10.3389/fenvs.2022.895622.

Ahmed, H.F., Hosseinian-Far, A., Khandan, R., Sarwar, D. and E-Fatima, K. 2022. Knowledge sharing in the supply chain networks: A perspective of supply chain complexity drivers. *Logistics*, 6(3), 66. doi.org/10.3390/logistics6030066.

Aigbavboa, C. 2015. Low-income housing residents' challenges with their government install solar water heaters: A case of South Africa. *Energy Procedia*, 75, pp. 495-501. doi.org/10.1016/j.egypro.2015.07.437.

Aitken, J., Bozarth, C. and Garn, W. 2016. To eliminate or absorb supply chain complexity: A conceptual model and case study. *International Journal of Supply Chain Management*, 21, pp. 759-774. doi.org/10.1108/SCM-02-2016-0044.

Akinbami, O.M., Oke, S.R. and Bodunrin, M.O. 2021. The state of renewable energy development in South Africa: An overview. *Alexandria Engineering Journal*, 60(6), pp. 5077-5093. doi.org/10.1016/j.aej.2021.03.065.

Ali, M., Uddin, Z., Banik, P. C., Hegazy, F. A., Zaman, S., Ambia, A.S.M., Siddique, M.K.B., Islam, R., Khanam, F., Bahalul, S.M., Sharkar, M.A., Hossain, F.M A. and Ahsan, G.U. 2023. Knowledge, attitude, practice and fear of COVID-19: A cross-cultural study. *International Journal of Mental Health and Addiction,* 21, pp. 1025-1040. doi.org/10.1007/s11469-021-00638-4.

Ali, S., Poulova, P., Akbar, A., Javed, H.M.U. and Danish, M. 2020. Determining the influencing factors in the adoption of solar photovoltaic technology in Pakistan: A decomposed Technology Acceptance Model Approach. *Economies,* 8(4), pp. 1-20. doi:10.3390/economies8040108

Aliyu, A.K., Modu, B. and Tan, C.W. 2018. A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria. *Renewable and Sustainable Energy Reviews*, 81, pp. 2502-2518. doi.org/10.1016/j.rser.2017.06.055.

American Solar Energy Society. 2024. Largest grassroots solar and sustainable living event in nation. Online Available: http://www.nationalsolartour.org. *(Accessed on 05 November 2024).*

Amit, K., Podder, Md. H., Naruttam, K.R. and Hemanshu, R.P. 2021. A chronological review of prospects of solar photovoltaic systems in Bangladesh: Feasibility study analysis, policies, barriers, and recommendations. *IET Renewable Power Generation*, 15, pp. 2109-2132. doi.org/10.1049/rpg2.12165.

Arroyo-López, P. and Carrete, L. 2019. Motivational drivers for the adoption of green energy: The case of purchasing photovoltaic systems. *Management Research Review,* 42(4), pp. 542-567. doi. 10.1108/MRR-02-2018-0070.

Azimoh, C.L., Klintenberg, P., Wallin, F. and Karlsson, B. 2015. Illuminated but not electrified: An assessment of the impact of solar home system on rural households in South Africa. *Applied energy*, 155, pp. 354-364. doi.org/10.1016/j.apenergy.2015.05.120.

Azimoh, C.L., Wallin, F., Klintenberg, P. and Karlsson, B. 2014. An assessment of unforeseen losses resulting from inappropriate use of solar home systems in South Africa. *Applied Energy*, 136, pp. 336-346. doi.org/10.1016/j.apenergy.2014.09.044.

Baker, L. and Phillips, J. 2019. Tensions in the transition: The politics of electricity distribution in South Africa. *Environment and Planning C: Politics and Space*, 37(1) pp. 177-196. doi: 10.1177/2399654418778590.

Bakri, J.A., Badmus, I. and Hammed, S.O. 2022. Comparative assessment of solar photovoltaic system and diesel generating set for energy sustainability in engineering buildings of Yaba College of Technology. *European Journal of Energy Research*, 2(4), pp. 10-16. doi:10.24018/ejenergy.2022.2.4.37.

Bedoud, K., Merabet, H. and Bahi, T. 2022. Power control strategy of a photovoltaic system with battery storage system. *Journal of Engineering and Applied Science,* 69,116. doi.org/10.1186/s44147-022-00163-8.

Bekun, F.V. 2024. Race to carbon neutrality in South Africa: What role does environmental technological innovation play? *Applied Energy,* 354, 122212. doi:10.1016/j.apenergy.2023.122212.

Bermudez, V. 2018. Japan, the new "El Dorado" of solar PV? *Journal of Renewable and Sustainable Energy*, *10*(2), 020401. doi.org/10.1063/1.5024431.

Bikam, P. and Mulaudzi, D.J. 2006. Solar energy trial in Folovhodwe South Africa: Lessons for policy and decision-makers. *Renewable Energy,* (31)10, pp. 1561-1571. doi.org/10.1016/j.renene.2005.07.015.

Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), pp. 77-101. doi.org/10.1191/1478088706qp063oa.

Bridle, R., Muzondo, C., Schmidt, M., Viswamohanan, A. and Geddes, A. 2022. South Africa's energy fiscal policies: An inventory of subsidies, taxes, and policies impacting the energy transition, International Institute for Sustainable Development. Online Available: https://www.iisd.org/publications/south-africa-energy-subsidies *(Accessed on 07 May 2022).*

Britannica, T. Editors of Encyclopedia. 2024. Eastern Cape. Encyclopedia Britannica. Online Available: https://www.britannica.com/place/Eastern-Cape-province-South-Africa.

Businesstech. 2023. South Africa's middle class is drowning in debt – and stresses are mounting Online Available: https://businesstech.co.za/news/finance/705879/south-africas-middle-class-is-drowning-in-debt-and-stresses-are *(Accessed on 23 August 2023).*

Businesstech. 2024. Load shedding and blackout warning for 2024. Online Available:

Bwalya, B., Chisola, M., Mushili, B., Kunda-Wamuwi, C., Kafwamba, D., Membele, G. and Imasiku, E. 2021. Load-shedding in Kitwe, Zambia: Effects and implications on household and local economies. *Development Southern Africa*. 39(3), pp. 1-18. doi: 10.1080/0376835X.2020.1870934.

Calitz, J. and Wright, J. 2020. Statistics of utility-scale power generation in South Africa in 2020 Online Available: http://hdl.handle.net/10204/11865. *(Accessed on 23 November 2022).*

Carley, S. and Konisky, D.M. 2020. The justice and equity implications of the clean energy transition. *Nature Energy*, 5, pp. 569-577. doi.org/10.1038/s41560-020-0641-6.

Castro-Rodríguez, F. and Miles-Touya. D. 2023. Impact of Spanish renewable support scheme reforms on the revenues of photovoltaic power plants. *Utilities Policy*, 80, 101476. doi:10.1016/j.jup.2022.101476.

Chang, K.C., Lin, W.M., Ross, G. and Chung, K.M. 2011. Dissemination of solar water heaters in South Africa. *Journal of Energy in Southern Africa*, 22(3), pp. 2-7. doi: 10.17159/2413-3051/2011/v22i3a3216.

Chao, J. 2020. How to accelerate solar adoption for the underserved. Online Available: https://newscenter.lbl.gov/2020/11/09/how-to-accelerate-solar-adoption-for-the-underserved/ *(Accessed on 23 November 2022).*

Chidembo, R., Francis, J. and Kativhu, S. 2022a. Rural households' perceptions of the adoption of rooftop solar photovoltaics in Vhembe district, South Africa. *Energies*, *15*(17)), 6157. doi.org/10.3390/en15176157.

Chidembo, R., Francis, J. and Kativhu, S. 2022b. A review of the achievements, weaknesses, and challenges of rural electrification through solar home systems in South Africa. *African Journal of Development Studies*, 2, pp. 191-211. doi.org/10.31920/2634-3649/2022/sin1a9.

Chipangamate, N.S. and Nwaila, G.T. 2024. Assessment of challenges and strategies for driving energy transitions in emerging markets: A socio-technological systems perspective. *Energy Geoscience*, 5(2), . 100257. doi.org/10.1016/j.engeos.2023.100257.

Christensen, J., Holst, C., and Molander, A. 2022. *Expertise, policy-making and democracy* (1st First ed.). London. Routledge. doi.org/10.4324/9781003106555.

City of Cape Town. 2022. Five-year integrated development plan. Online Available: http: baker-phillips-2018-tensions-in-the-transition-the-politics-of-electricity-distribution-in-south-africa PDF (resource.capetown.gov.za). *(Accessed on 02 October 2024).*

Clark, W.W. (ed.) 2018. *Sustainable cities and communities design handbook* (Second Editioned.)., Butterworth. Heinemann.

Coleman, N., Esmalian, A., Lee, C., Gonzales, E. Koirala, P. and Mostafavi, A. 2023. Energy inequality in climate hazards: Empirical evidence of social and spatial disparities in managed and hazard-induced power outages. *Sustainable Cities and Society*, 92(4), 104491. doi.10.1016/j.scs.2023.104491.

Conway, D., Robinson, B., Mudimu, P., Chitekwe, T., Koranteng, K. and Swilling, M. 2019. Exploring hybrid models for universal access to basic solar energy services in informal settlements: Case studies from South Africa and Zimbabwe. *Energy Research and Social Science*, 56(1), 101202. doi.org/10.1016/j.erss.2019.05.012.

Cook, J.J. and Bird, L.A. 2018. Unlocking solar for low-and moderate-income residents: A matrix of financing options by resident, provider, and housing type. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70477. Online Available: https://doi.org/10.2172/1416133. *(Accessed on 12 April 2023)*

Cooper, D. and Schindler, P. 2016. *Business Research Methods*. McGraw-Hill Higher Education. New York, NY.

Creamer's Media Engineering News (CMEN). 2024. Opinion: A call for clear, uniform solar policy in South Africa. Online Available: https://www.engineeringnews.co.za/article/opinion-a-call-for-clear-uniform-solar-policy-in-south-africa-2024-04-24. *(Accessed on 05 November 2024).*

Culiberg, B., Cho, H., Kos Koklic, M. and Zabkar, V. 2023. The role of moral foundations, anticipated guilt and personal responsibility in predicting anti-consumption for environmental reasons. *Journal of Business Ethics*, 182, pp. 465-481. doi.org/10.1007/s10551-021-05016-7.

Curry, C., Cherni, J.A., and Mapako, M. 2017. The potential and reality of the solar water heater programme in South African townships: Lessons from the City of Tshwane. *Energy Policy*, 106, 75-84. doi.org/10.1016/j.enpol.2017.03.028.

D'Agostino, A.L., Sovacool, B.K. and Bambawale, M.J. 2011. And then what happened? A retrospective appraisal of China′s renewable energy development project (REDP). *Renewable Energy,* 36(11), pp. 3154-3165. doi:10.1016/j.renene.2011.03.017.

Dagnachew, A.G., Hof, A.F., Roelfsema, M.R. and van Vuuren, D.P. 2020. Actors and governance in the transition toward universal electricity access in Sub-Saharan Africa. *Energy Policy*, 143, 111572. doi 10.1016/j.enpol.2020.11157.

de Groot, J.I.M. and Steg, L. 2007. Value orientations and environmental beliefs in five countries- Validity of an instrument to measure egoistic, altruistic and biospheric value orientations. *Journal of Cross-Cultural Psychology*, *38*(3), pp. 318-332. doi.org/10.1177/0022022107300278.

Denzin, N.K., and Lincoln, Y.S. 1998. *Collecting and interpreting qualitative material*. Thousand Oaks, CA: Sage.

Department of Energy South Africa. 2019. Annual report 2018/19. Online Available: http//www.gov.za. *(Accessed on 28 June 2022).*

Dhoha, A. and Ramendra, T. 2019. Impact of cognition, affect, and social factors on technology adoption. *International Journal of Technology Marketing,* (13)2, 178. . doi: 10.1504/ijtmkt.2019.102266.

Diaz, P. Adler, C. and Patt, A. 2017. Do stakeholders' perspectives on renewable energy infrastructure pose a risk to energy policy implementation? A case of a hydropower plant in Switzerland. *Energy Policy,* 108, pp. 21-28. doi: 10.1016/j.enpol.2017.05.033.

Ding, Y., Si, T., Xu, K., Zhang, S. and Wang, Z. 2023. Spatial disparity of utility-scale solar energy and the role of solar policy in the U.S. *Energy Strategy Review*, 50, 101179. doi.org/10.1016/j.esr.2023.101179.

Dippenaar, J., Merven, B., Euston-Brown, M. and Borchers, M. 2021. A system cost analysis of embedded generation vs utility-scale solar PV. Online Available: https://www.cityenergy.org.za. *(Accessed on 20 October 2024).*

Donev, G., van Sark, W.G. J.H.M., Blok, K. and Dintchev, O. 2012. Solar water heating potential in South Africa in dynamic energy market conditions. *Renewable and Sustainable Energy Reviews*, 16(5), 3002-3013. doi.org/10.1016/j.rser.2012.01.065.

Dutt, W. 2020. Understanding the barriers to the diffusion of rooftop solar: A case study of Delhi (India). *Energy Policy*, 144(2), 111674. doi.org/10.1016/j.enpol.2020.111674.

Eckersley, R. and Fitz Henry, E. 2023. What is a 'just' transition to net zero - and why is Australia struggling to get there? Online Available: https://theconversation.com/what-is-a-just-transition-to-net-zero-and-why-is-australia *(Accessed on 07 November 2023).*

Ehresman, T.G. and Okereke, C. 2015. Environmental justice and conceptions of the green economy. *International Environmental Agreements: Politics, Law and Economics,* 15 (1), pp. 13-27. doi.org/10.1007/s10784-014-9265-2.

Energy Central. 2022. Ramaphosa's 10-point power crisis plan: What you need to know. Online Available: https://energycentral.com/news/ramaphosa%E2%80%99s-10-point-power-crisis-plan-what-you-need-know. *(Accessed on 31 October 2022).*

Erero, J.L. 2023. Impact of loadshedding in South Africa: A CGE analysis. *Journal of Economics and Political Economy,* 10(2), pp. 78-94. doi:journals.econsciences.com/index.php/JEPE/article/view/2448.

Eskom. 2019. Generation system adequacy for South Africa. Medium term system adequacy outlook. Online Available: http//:www.eskom.co.za. *(Accessed on 16 February 2022).*

Eskom. 2020. Integrated report 31 March 2020. Restoring trust. [Online] Available: https://www.eskom.co.za. *(Accessed on 17 February 2022).*

Eskom. 2021. Customer care. Tariffs and charges. Online Available:

Eskom. 2023. Eskom clarifies the 18.65% tariff increase. Online Available: https://www.eskom.co.za/eskom-clarifies-the-18-65-tariff-increase. *(Accessed on 16 April 2023).*

Eskom. 2024. Eskom generation adequacy report-medium term. Online Available: https://www.eskom.co.za/wp-content/uploads/2024/02/Weekly_System_Status_Report_2024_w7.pdf. *(Accessed on 18 October 2024).*

Eskom. 2024. Small-scale embedded generation. Online Available: https://www.eskom.co.za/distribution/small-scale-embedded-generators. *(Accessed on 02 September, 2024).*

Esterhuizen, N. 2019. Impact of load shedding on consumers. Online Available: https://www.bbrief.co.za/author/nico-esterhuizen *(Accessed on 16 October 2022).*

Eti, S., Yüksel, S., Dinçer, H., Kalkavan, H., Hacioglu, U., Mikhaylov, A., Danish, M. and Pinter, G. 2024. Assessment of technical and financial challenges for renewable energy project alternatives. *Cleaner Engineering and Technology*, 18, 100719. doi.org/10.1016/j.clet.2023.100719.

Etongo, D. and Naidu, H. 2022. Determinants of household adoption of solar energy technology in Seychelles in a context of 100% access to electricity. *Discover Sustainability,* 3(38), 108. doi.org/10.1007/s43621-022-00108-4.

Faiers, A. and Neame, C. 2006. Consumer attitudes towards domestic solar power systems. *Energy Policy*, 34(14), pp. 1797-1806. doi.org/10.1016/j.enpol.2005.01.001.

Fairbrother, M. 2012. Rich people, poor people, and environmental concern: evidence across nations and time. *European Sociological Review,* 29(5). pp. 910-922. doi:10.1093/esr/jcs068.

Falagas, M.E., Pitsouni, E.I., Malietzis, G.A. and Pappas, G. 2008. Comparison of Pub Med, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *FASEB Journal*, 22(2), pp 338-342. doi: 10.1096/fj.07-9492LSF.

Fan, J. and Zhou, X. 2023. Optimization of a hybrid solar/wind/storage system with bio-generator for a household by emerging metaheuristic optimization algorithm. *Journal of Energy Storage*, 73(3), 108967. doi.org/10.1016/j.est.2023.108967.

Finn, A., Murray, L. and Ranchlod, V. 2014. *Post-apartheid poverty and inequality trends*. In H. Bhorat, A. Hirsch, R. Kanbur, and M. Ncube (Eds.). *The Oxford companion to the economics of South Africa*, pp. 292-299. doi: 10.1093/acprof:oso/9780199689248.003.0038. SSRN. Cornell University.

Fischer, A.R.H., Wentholt, M.T.A. and Frewer, L.J. 2014. Expert involvement in policy development: A systematic review of current practice. *Science and Public Policy*, 41(3), pp. 332-343. doi: 10.1093/scipol/sct062.

Francis, J.J., Johnston, M., Robertson, C., Glidewell, L., Entwistle, V., Eccles, M.P. and Grimshaw, J.M. 2010. What is an adequate sample size? Operationalising data saturation for theory-based interview studies. *Psychological Health*, 25(10), pp. 1229-1245. doi.org/10.1080/08870440903194015.

Frederiks, E.R., Stenner, K. and Hobman, E.V. 2015. The socio-demographic and psychological predictors of residential energy consumption: A comprehensive review. *Energies,* 8(1), pp. 573-609. doi.org/10.3390/en8010573.

Gao, X. and Zhou, S. 2022. Solar adoption inequality in the US: Trend, magnitude, and solar justice policies. *Energy Policy*, 169, 113163. doi:10.1016/j.enpol.2022.113163.

Ghaboulian-Zare, S.G., Hafezi, R., Alipour, M., Parsaei T.R. and Stewart, R.A. 2021. Residential solar water heater adoption behaviour: A review of economic and technical predictors and their correlation with the adoption decision. *Energies*, 14(20), 6630. doi.org/10.3390/en14206630.

Ghosh, A. and Prasad, V.K. 2024. Evaluating the influence of environmental factors on household solar PV pro-environmental behavioral intentions: A meta-analysis review. *Renewable and Sustainable Energy Reviews*, 190, 114047. doi.org/10.1016/j.rser.2023.114047.

Githahu, M. 2023. Cape Town offers businesses, residents cash for power but experts say scheme 'is too costly'. Online Available: Cape Town offers businesses, residents cash for power but experts say scheme 'is too costly' (iol.co.za). *(Accessed on 24 July 2023).*

Gray, J.E., Hamilton, M.C., Hauser, A., Janz, M., Peters, J.P. and Taggart, F. 2012. Scholarish: Google Scholar and its value to the sciences. *Issues in Science and Technology Librarianship*,70, 159. . doi.org/10.1108/OIR-07-2014-0159.

Groenendaal, B. 2023. Chaotic leadership leaves South Africans in the dark. Online Available: https://www.pv-magazine.com/2023/08/19/weekend-read-chaotic-leadership-leaves-south-africans-in-the-dark. *(Accessed on 30 September 2023).*

Gupta, R. Pena-Bello, A., Streicher, K.N, Roduner, C. Farhat, Y. Thöni, T., Patel, M.K. and Parra, D. 2021. Spatial analysis of distribution grid capacity and costs to enable massive deployment of PV, electric mobility and electric heating. *Applied Energy*, 287, 116504. doi.org/10.1016/j.apenergy.2021.116504.

Gusenbauer, M. and Haddaway, N.R. 2019. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods*, 11(2), pp. 181-217. doi: 10.1002/jrsm.1378.

Guta, D.D. 2018. Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of Cleaner Production*, 204, pp. 193-204. doi.org/10.1016/j.jclepro.2018.09.016.

Haddaway, N.R., Macura, B., Whaley, P. and Pullin, A.S. 2018. ROSES Reporting Standards for Systematic Evidence Syntheses: Pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence*,7, p.p.1-8. doi 10.1186/s13750-018-0121-7.

Hansen, K. and Świderska, A. 2023. Integrating open- and closed-ended questions on attitudes towards outgroups with different methods of text analysis. *Behaviour Research*, . 56(5), pp. 4802-4822. doi.org/10.3758/s13428-023-02218-x.

Hendricks, D. 2016. Factors influencing adoption of PV technology as an alternative energy in households: A case of Parkhurst, South Africa. [Dissertation, University of Pretoria, Gordon Institute of Business Science]. https://repository.up.ac.za/handle/2263/24826.

Herman, R., Cornelia, N. and Nicolae, M.J. 2023. The influence of the increase in energy prices on the profitability of companies in the European Union. *Sustainability*, 15(21), 15404. doi.org/10.3390/su152115404.

Hess, C.E.E. and Ribeiro, W.C. 2016. Energy and environmental justice: closing the gap. *Environmental Justice*, 9(5), pp. 153-158. doi:10.1089/env.2016.0017.

https://businesstech.co.za/news/energy/739825/load-shedding-and-blackout-warning -for-2024/#:~:text=with%20outages%20being-,in,-effect%20for%2079. *(Accessed on 18 February 2024).*

https://www.ESKOM.co.za/CustomerCare/TariffsAndCharges/Pages/Tariffs_And_Charges.aspx *(Accessed on 16 April 2023).*

Ibegbulam, C., Adeyemi, O. and Fogbonjaiye, O. 2023. Adoption of solar PV in developing countries: Challenges and opportunity. *International Journal of Physical Sciences Research,* 7(1), pp. 36-57. doi.10.37745/10.37745/ijpsr.17/vol7n13657.

Ikejemba, E.C.X. and Schuur, P.C. 2018. Analyzing the impact of theft and vandalism in relation to the sustainability of renewable energy development projects in sub-Saharan Africa. *Sustainability*, 10(3), p. 814. doi.org/10.3390/su10030814.

International Energy Agency (IEA). 2018. PV annual report 2018. Online Available: iea-pvps.org. *(Accessed on 16 February 2022).*

International Energy Agency (IEA). 2019. Africa energy outlook: World energy outlook special report. Online Available: https://www.iea.org/reports/africa-energy-outlook-2019. *(Accessed on 16 February 2022).*

International Energy Agency (IEA). 2020. Data and statistics. Online Available: https://www.iea.org/data-and-statistics (*Accessed March 30, 2022).*

International Energy Agency (IEA). 2021. World Energy Outlook 2021. Online Available: https://www.iea.org/reports/africa-energy-outlook-2021. *(Accessed on 21 October 2024).*

International Energy Agency (IEA). 2022. World energy outlook 2022 – analysis. Online Available: https://www.iea.org/reports/world-energy-outlook-2022. *(Accessed on 19 September 2023).*

International Energy Agency (IEA). 2023. SDG7: Data and Projections, IEA, Paris. Online Available: https://www.iea.org/reports/sdg7-data-and-projections. *(Accessed on 21 October 2024).*

IRENA. 2022. World energy transitions outlook: 1.5°C Pathway, international renewable energy agency, Abu Dhabi Online Available: http:// www.irena.org/publications. *(Accessed on 24 July 2023).*

Irfan, M., Zhao, Z.Y., Ahmad, M. and Mukeshimana, M.C. 2019. Solar energy development in Pakistan: Barriers and policy recommendations. *Sustainability*, 11, p.1206. doi.org/10.3390/su11041206.

Islam, N. and Winkel, J. 2021. United Nations Department of Economic and Social Affairs climate change and social inequality. Online Available: https://www.un.org/en/desa/climate-change-and-social-inequality. *(Accessed on 20 October 2024).*

Islam, T. and Meade, N. 2013. The impact of attribute preferences on adoption timing: the case of photovoltaic (PV) solar cells for household electricity generation. *Energy Policy,* 55, pp. 521-530. doi.org/10.1016/j.enpol.2012.12.041.

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A. and Hertwich, E.G. 2016. Environmental impact assessment of household consumption. *Journal of Industrial Ecology*, 20, pp. 526-536. doi:10.1111/jiec.12371.

Jacobsson, S. and Lauber, V. T. 2006. The politics and policy of energy system transformation-Explaining the German diffusion of renewable energy technology. *Energy Policy*, 34(3), pp. 56-276. doi:10.1016/j.enpol.2004.08.029.

Jadhav, A.S., Chembe D.K., Strauss J.M. and Van Niekerk J.L. 2017. Status of solar technology implementation in the Southern African Developing Community (SADC) region. *Renewable and Sustainable Energy Reviews,* 73, pp. 622-631. doi:10.1016/j.rser.2017.01.113.

Janz, N.K. and Becker, M.H. 1984. The health belief model: A decade later. *Health education quarterly*, 11(1), pp.1-47. doi: 10.1177/109019818401100101.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H. and Rehner, R. 2016. Energy justice: A conceptual review. *Energy research & social science*, 11, pp. 174-182. doi.org/10.1016/j.erss.2015.10.004.

Jordan, M., Johnson, M., Wolf, A., DeLeon, X.A., Ramos, M., Morrissey, M.M., Johnson, A., Currier, S. R. and D'Amico, L. 2019. *Developing Photovoltaics Curriculum for Middle and Upper Grades: Using Solar to Engineer Our Energy Future (P12 Resource Exchange)* Paper presented at 2019 ASEE Annual Conference and Exposition, Tampa, Florida. doi:10.18260/1-2-32642.

Jude, T. 2023. The most visually appealing solar panels, ranked. Architectural digest. Online Available: https://www.architecturaldigest.com/reviews/solar/most-visually-appealing-solar-panels. *(Accessed on 09 September 2024).*

Jumayev, A.Y and Atayev, E. 2022. Pilot projects of industrial photovoltaic solar stations. *IOP Conference Series: Earth and Environmental Science*, 979(1), 012142.. doi:10.1088/1755-1315/979/1/012142.

Kambule, N., Yessoufou, K., Nwulu, N. and Mbohwa, C. 2018. Temporal analysis of electricity consumption for prepaid metered low- and high-income households in Soweto, South Africa. *African Journal of Science, Technology, Innovation and Development*, *11*(3), pp. 375-382. doi.org/10.1080/20421338.2018.1527983. Kambule, N., Yessoufou, K., Nwulu, N. and Mbohwa, C. 2021. Temporal analysis of electricity consumption for prepaid metered low and high-income households in Soweto, South Africa. *African Journal of Science, Technology, Innovation and Development*, 11, pp. 375-382. doi.org/10.1080/20421338.2018.1527983.

Kapoor, K.K. and Dwivedi, Y.K. 2020. Sustainable consumption from the consumer's perspective: Antecedents of solar innovation adoption. *Resources, conservation and recycling*, 152, 104501. doi.org/10.1016/j.resconrec.2019.104501.

Kappner, K., Letmathe, P. and Weidinger, P. 2023. Causes and effects of the German energy transition in the context of environmental, societal, political, technological, and economic developments. *Energy, Sustainability and Soc*iety, 13(1), p. 28. doi.org/10.1186/s13705-023-00407-2.

Kereeditse, M.K. and Mpundu, M. 2021. Analysis of household debt in South Africa pre- and post-low-quality asset financial crisis. *International Journal of Economics and Financial Issues*, 11(5), pp. 114-12. doi.org/10.32479/ijefi.11476.

Khattak, N.S.R., Hassnain, U.I.S., Shah, W. and Mutlib, B. 2006. Identification and removal of barriers for renewable energy technologies in Pakistan. *2006 International Conference on Emerging Technologies,* pp. 397-402. doi: 10.1109/ICET.2006.335984.

Khine, M.M. and Langkulsen, U. 2023. The implications of climate change on health among vulnerable populations in South Africa: A systematic review. *International Journal of Environmental Research and Public Health*, 20(4), 3425. doi: 10.3390/ijerph20043425.

Korsten, N., Brent, A., Sebitosi, B. and Kritzinger, K. 2017. The impact of residential rooftop solar PV on municipal finances: An analysis of Stellenbosch. *Journal of Energy in Southern Africa*, 28(2), pp. 29-39. doi.org/10.17159/2413-3051/2017/v28i2a1740.

Kristy E. Langerman, K.E., Garland, R.M., Feig, G., Mpanza, M. and Wernecke, B. 2023. South Africa's electricity disaster is an air quality disaster, too. *Clean Air Journal*, 33(1), p.p. 1-2 doi.org/10.17159/caj/2023/33/1.15799.

Kritzinger, K. and Covary, T. 2016. Review of South Africa’s solar water heating rebate programme. Online Available: https://www.bing.com/search?q=Kritzinger%2C+Karin+%26+Covary%2C+Theo.+(2016). *(Accessed on 09 September 2024).*

Kritzinger, K., Scholtz, L. and N. Korsten. 2020. Understanding and managing residential solar rooftop PV: Decision-making for the future. Briefing paper to WWF South Africa, Cape Town, South Africa. Online Available: doi:10.13140/RG.2.2.24278.27202. *(Accessed on 09 September 2024).*

Kumar, V., Hundal, B.S. and Kaur, K. 2019. Exploring the service quality determinants of solar product dealers. *Asia-Pacific Journal of Management Research and Innovation*, 15(1), pp. 27-38. doi.org/10.1177/2319510X1982933.

Kyprianou, I., Serghides, D.K., Varo, A., Gouveia, J.P., Kopeva, D. and Murauskaite, L. 2019. Energy poverty policies and measures in 5 EU countries: A comparative study. Energy Build, 196, pp. 46-60. doi.org/10.1016/j.enbuild.2019.05.003

Lacey-Barnacle, M., Robison, R., and Foulds, C. 2020. Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. *Energy for Sustainable Development,* 55, pp. 122-138. doi.org/10.1016/j.esd.2020.01.010.

Lan, H., Cheng, B., Goub, Z. and Yu, R. 2020. An evaluation of feed-in tariffs for promoting household solar energy adoption in Southeast Queensland, Australia. *Sustainable Cities and Society*, 53. 110458. doi.org/10.1016/j.rser.2020.110458.

Leary, J., Leach, M., Batchelor, S., Scott, N. and Brown, E. 2021. Battery-supported cooking: A transformative opportunity for 2.6 billion people who still cook with biomass. *Energy Policy*, 159. 112619. doi.org/10.1016/j.enpol.2021.112619.

Lemaire, X. 2011. Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. *Energy for Sustainable Development*, 15(3), pp. 277-283. doi.org/10.1016/j.esd.2011.07.005.

Lin, B. and Okyere, M.A. 2020. Multidimensional energy poverty and mental health: micro-level evidence from Ghana. *International Journal oOf Environmental Research and Public Health*, 17(18),. 6726. doi.org/10.3390/ijerph17186726.

Lingard, L. 2019. Beyond the default colon: Effective use of quotes in qualitative research. *Perspectives on Medical Education,* 8(6), pp. 360-364. doi: 10.1007/s40037-019-00550-7.

Liu, X., O'Rear, E.G., Tyner, W.E. and Pekny, J.F. 2014. Purchasing vs. leasing: A benefit-cost analysis of residential solar PV panel use in California. *Renewable Energy: An International Journal*, 66, pp. 770-774. doi: 10.1016/j.renene.2014.01.026.

Lo, T.S.K., Mah, D.N., Wang, G., Leung, M.K H., Lo, A.Y. and Hills, P. 2018. Barriers to adopting solar photovoltaic systems in Hong Kong. *Energy and Environment*, 29(5), pp. 649-663. doi.org/10.1177/0958305X18757402.

Macharia, S. 2024. Solar PV in developing countries: Overcoming challenges and driving adoption. Online Available: https://www.linkedin.com/pulse/solar-pv-developing-countries-overcoming-challenges-driving-macharia-fs7o. *(Accessed on 06 May 2024).*

Maghami, M. R., Pasupuleti, J. and Ling, C. M. 2023. Comparative analysis of smart grid solar integration in urban and rural networks. *Smart Cities*, 6(5), pp. 2593-2618. doi.org/10.3390/smartcities6050117. *(Accessed on 06 May 2024).*

Magni, C.A., Marchioni, A. and Baschieri, D. 2022. Impact of financing and payout policy on the economic profitability of solar photovoltaic plants. *International Journal of Production Economics*, 244. 108338. doi.org/10.1016/j.ijpe.2021.108338.

Mahlobo, D.D., Ndarana, T., Grab, S. and Engelbrecht, F. 2019. Integrated climatology and trends in the subtropical Hadley cell, sunshine duration and cloud cover over South Africa. *International Journal of Climatology*, 39(4), 1805-1821. doi.org/10.1002/joc.5917.

Malik, M.I., Hyder Ahmad, I., Malik, S., Hussain, S., Saleem, S. and Imtiaz, S. 2020. Renewable energy products and customer's purchase intentions having environmental concern. *International Journal of Energy Economics and Policy,* 10 (6), pp.14-21. doi: 10.32479/ijeep.10427.

Maqbool, R., Deng, X. and Rashid, Y. 2020. Stakeholders' satisfaction as a key determinant of critical success factors in renewable energy projects. *Energy Sustainability and Society,* 10, pp. 1-15 (28). doi.org/10.1186/s13705-020-00259-0.

Marchetti-Mercer, M.C. 2023. Resilience is not enough: The mental health impact of the ongoing energy crisis in South Africa. *South African Journal of Science*, 119(9/10). doi.org/10.17159/sajs.2023/16608.

Marshall, M.N. 1996. The key informant techniques. *Family Practice,* 13: pp. 92-97.

Masuku, B. 2024. Rethinking South Africa's household energy poverty through the lens of off-grid energy transition. *Development Southern Africa*, pp. 1-24. doi: 10.1080/0376835X.2023.2300411.

McCauley, D. and Heffron, R. 2018. Just transition: Integrating climate, energy and environmental justice. *Energy Policy*, 119, pp. 1-7. doi: 10.1016/j.enpol.2018.04.014.

McKay, T. and Hendricks, D. 2022. Pitiful rooftop solar uptake in sunny South Africa: A policy, funding and service delivery perspective. *Frontiers in Sustainable Cities*, 4, 969040. doi.org/10.3389/frsc.2022.969040.

McKenna, E., Pless, J. and Darby, S.J. 2018. Solar photovoltaic self-consumption in the UK residential sector: New estimates from a smart grid demonstration project. *Energy Policy*, 118, pp. 482-491. doi.org/10.1016/j.enpol.2018.04.006.

Meried, E. W. 2021. Rural household preferences in transition from traditional to renewable energy sources: The applicability of the energy ladder hypothesis in North Gondar Zone. *Heliyon*, 7(11), e08418. doi.org/10.1016/j.heliyon.2021.e08418.

Mhlongo, L. 2020. A critical analysis of South Africa's system of government: from a disjunctive system to a synergistic system of government. *Obiter*, 41(2), pp. 257-274. doi: 10.17159/obiter.v41i2.9149.

Milewska, B. and Milewski, D. 2023. The impact of energy consumption costs on the profitability of production companies in Poland in the context of the energy crisis. *Energies*, 16(18), 6519. . doi.org/10.3390/en16186519.

Mirzania, P., Gordon, J.A., Balta-Ozkan, N., Sayan, R.C. and Marais, L. 2023. Barriers to powering past coal: Implications for a just energy transition in South Africa. *Energy Research & Social Science*, 101, . 103122. doi.org/10.1016/j.erss.2023.103122.

Monyai, P., Chivanga, S.C. and Katsande, N. 2023. Inequalities in access to energy in informal settlements: towards energy justice in Gqeberha and Komani in South Africa. *Water-Energy Nexus*, 6, pp.1-5. doi.org/10.1016/j.wen.2023.01.001.

Moolman, S. 2024. 2022 update: Eskom tariff increases vs inflation since 1988 (with projections to 2024). Online Available: https://poweroptimal.com/2021-update-eskom-tariff-increases-vs-inflation-since-1988. *(Accessed on 21 October 2024).*

Mordor Intelligence. 2022. South Africa solar photovoltaic (PV) market - growth, trends, covid-19 impact, and forecasts (2022 - 2027). Online Available: https://www.mordorintelligence.com/industry-reports/south-africa-solar-power-market-industry. *(Accessed on 06 May 2022).*

Morrison, E.J. 2022. Unbundling, markets, and regulation. In: Hafner, M., Luciani, G. (eds) *The Palgrave handbook of international Energy Economics*. Palgrave Macmillan, Cham. doi.org/10.1007/978-3-030-86884-0_24.

Mucina, L. and Rutherford, M.C. (eds). 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Strelitzia, 19. South African National Biodiversity Institute. Pretoria. South African National Biodiversity Institute.

Muellmann, S., Brand, T., Jürgens, D., Gansefort, D. and Zeeb, H. 2021. How many key informants are enough? Analysing the validity of the community readiness assessment. *BMC research notes*, 14, pp.1-6. doi.org/10.1186/s13104-021-05497-9.

Mukumba, P. and Chivanga, S.Y. 2023. "An overview of renewable energy technologies in the Eastern Cape province in South Africa and the rural households' energy poverty coping strategies. *Challenges*, 14(1), p. 19. doi.org/10.3390/challe14010019.

Mulaudzi, S.K., Bull, S. and Makhado, R.A. 2022. Potential of households' solar PV consumption in South Africa. *African Journal of Science, Technology, Innovation and Development*, 14(3), pp. 730-739. doi: 10.1080/20421338.2021.1894728.

Mutumbi, U., Thondhlana, G. and Ruwanza, S. 2021. Reported behavioural patterns of electricity use among low-income households in Makhanda, South Africa. *Sustainability,* 13. doi.org/10.3390/su13137271.

Mutumbi, U., Thondhlana, G. and Ruwanza, S. 2022. Co-designed interventions yield significant electricity savings among low-income households in Makhanda South Africa. *Energies*, 15(7), 2320. doi.org/10.3390/en15072320.

Mutumbi, U., Thondhlana, G. and Ruwanza, S. 2022. The status of household electricity use behaviour research in South Africa between 2000 and 2022. *Energies*, 15(23), 9018. doi.org/10.3390/en15239018.

National Policy Development Framework. 2020. Approved by cabinet on 2 December 2020. Online Available: https://www.gov.za/sites/default/files/gcisdocument/202101/national-policy-development-framework-2020. *(Accessed on 21 October 2024).*

Netshiozwi, E. E. 2019. Causes of failure of the South African solar water heating programme and the forgone social benefits. *Review of Social Sciences*, 4(1), pp. 1-15.. doi.org/10.18533/rss.v3i1.136.

News24. 2023. Cape Town eyes cheaper feed-in meters to cut cost of selling power back to the grid | Business. Cape Town eyes cheaper feed-in meters to cut cost of selling power back to the grid | Business. Online Available: https://www.news24.com/fin24/climate_future/energy/cape-town-eyes-cheaper-feed-in-meters-to-cut-cost-of-selling-power-back-to-the-grid-20230530. *(Accessed on 09 September 2024).*

Ngarava, S., Zhou, L., Ningi, T., Chari, M.M. and Mdiya, L. 2022. Gender and ethnic disparities in energy poverty: The case of South Africa. *Energy Policy*, 161, 112755. doi: 10.1016/j.enpol.2021.112755.

Nwaigwe, K.N., Mutabilwa, P. and Dintwa, E. 2019. An overview of solar power (PV systems) integration into electricity grids. *Materials Science for Energy Technologies,* 2 (3), pp. 629-633. doi.org/10.1016/j.mset.2019.07.002.

Ohunakin, O.S., Adaramola, M.S., Olanrewaju, M. and Fagbenle, R.O. 2014. Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews*, 32, pp. 294-301. doi:10.1016/j.rser.2014.01.014.

Ondraczek, J. 2014. Are we there yet? Improving solar PV economics and power planning in developing countries: the case of Kenya. *Renewable and Sustainable Energy Revolution*, 30, pp. 604-615. doi: 10.1016/j.rser.2013.10.010.

Ortega, N., Curto, A., Dimitrova, A., Nunes, J., Rasella, D., Sacoord., C. and Tonne, C. 2021. Health and environmental impacts of replacing kerosene-based lighting with renewable electricity in East Africa. *Energy for Sustainable Development,* 63, pp. 16-23. doi: 10.1016/j.esd.2021.05.004.

Oteng, D., Zuo, J. and Sharifi, E. 2022. Environmental emissions influencing solar photovoltaic waste management in Australia: An optimised system network of waste collection facilities. *Journal of Environmental Management*, 314, 115007. doi.org/10.1016/j.jenvman.2022.115007.

Pagliuca, M., Panarello, D. and Punzo, G. 2022. Values, concern, beliefs, and preference for solar energy: A comparative analysis of three European countries. *Environmental Impact Assessment Review*, 93, 106722. doi.org/10.1016/j.eiar.2021.106722.

Palm, J. 2018. Household installations of solar panels – motives and barriers in a 10-year perspective. *Energy Policy*, 113, pp. 1-8. doi.org/10.1016/j.enpol.2017.10.047.

Pandey, S.K., Gupta, B. and Kapoor, S. 2022. Pre-installation analysis of a solar grid-connected photovoltaic system for a countryside energization in Jharkhand via "PV system, India, 2022 *International Conference on Computer, Power and Communications (ICCPC),* Chennai, India, 2022, pp. 264-269. doi: 10.1109/ICCPC55978.2022.10072149.

Parsad, C., Mittal, S. and Krishnankutty, R. 2020. A study on the factors affecting household solar adoption in Kerala, India. *International Journal of Productivity and performance Management*, 69 (8), pp. 1695-1720. doi: 10.1108/ijppm-11-2019-0544.

Pathak, S.K., Sharma, V., Chougule, S.S. and Goel, V. 2022. Prioritization of barriers to the development of renewable energy technologies in India using integrated modified Delphi and AHP method. *Sustainable Energy Technologies and Assessments,* 50(5), 101818. doi: 10.1016/j.seta.2021.101818

Patience, S. 2024. Overcoming the barriers to rooftop solar energy. Online Available: https://www.pbctoday.co.uk/ *(Accessed on 29 February 2024).*

Perry, K.K. 2020. For politics, people, or the planet? The political economy of fossil fuel reform, energy dependence and climate policy in Haiti. *Energy Research & Social Science*, 63, 101397. doi.org/10.1016/j.erss.2019.101397.

Peter, M. 2023. Barriers to renewable energy adoption in Nigeria. Online Available: https://www.linkedin.com/pulse/barriers-renewable-energy-adoption-nigeria-michael-peter. *(Accessed on 09 September 2024).*

Philippsen, J.S., Angeoletto, F.H.S and Santana, R.G. 2017. Education level and income are important for good environmental awareness: A case study from south Brazil. *Ecologia Austral.* 27, pp. 39-44.

Podder, A.K., Habibullah, M., Roy, N.K. and Pota, H.R. 2021. A chronological review of prospects of solar photovoltaic systems in Bangladesh: Feasibility study analysis, policies, barriers, and recommendations. *IET Renewable Power Generation*, *15*, pp. 2109-2132. doi: 10.1049/rpg2.12165.

Poortinga, W., Steg, L. and Vlek, C. 2004. Values, environmental concern, and environmental behavior: A study into household energy use. *Environment and Behavior*, 36(1), pp. 70-93. doi.org/10.1177/0013916503251466.

Poruschi, L. and Ambrey, C.L. 2019. Energy justice, the built environment, and solar photovoltaic (PV) energy transitions in urban Australia: A dynamic panel data analysis. *Energy Research & Social Science*, 48, pp. 22-32. doi.org/10.1016/j.erss.2018.09.008.

Prajapati, B. 2022. Factors affecting customer satisfaction towards solar panel. *International Journal of Marketing and Human Resource Research,* 3(2), pp. 52-61. doi:10.47747/ijmhrr.v3i2.679.

Prete, C.L., Hogan, W.W., Liu, B. and Wang, J. 2019. Cross-product manipulation in electricity markets, microstructure models and asymmetric information. *Energy Journal*, 40(5), pp. 221-246. doi: 10.5547/01956574.40.5.

Property Review. 2024. Solar financing options offered by South Africa's big banks. Online Available: https://www.propertyreview.co.za/post/solar-financing-options-offered-by-south-africa-s-big-banks. *(Accessed on 18 October 2024).*

Qin, L., Chen, W. and Sun, L. 2022. Impact of energy poverty on household quality of life-based on Chinese household survey panel data. *Journal of Cleaner Production,* 366, 132943. doi.org/10.1016/j.jclepro.2022.132943.

Qudrat-Ullah, H., Akrofi, M.M. and Kayal, A. 2020. Analyzing actors' engagement in sustainable energy planning at the local level in Ghana: An empirical study, *Energies*, 13(8), 2028. doi:10.3390/en13082028.

Qureshi, T.M., Ullah, K. and Arentsen, M. 2017. Factors responsible for solar PV adoption at household level: A case of Lahore, Pakistan. *Renewable & amp; Sustainable Energy Reviews*, 78, pp. 754-763. doi:10.1016/j.rser.2017.04.020.

Rai, V. and Beck, A.L. 2015. Public perceptions and information gaps in solar energy in Texas. *Environmental Research Lett*er, 10(7), 074011. . doi 10.1088/1748-9326/10/7/074011.

Rai, V., Reeves, D.C. and Margolis, R. 2016. Overcoming barriers and uncertainties in the adoption of residential solar PV. *Renewable Energy,* 89, pp. 498-505. doi: 10.1016/j.renene.2015.11.080.

Ratepayers Revolt. 2024. Ndlambe municipality targets solar users with new policy. Online Available: https://ratepayersrevolt.co.za/2024/09/09/ndlambe-municipality-targets-solar-users-with-new-policy/. *(Accessed on 05 October 2024).*

Raymond, J., Kihedu, J. and Kimambo. C.M.Z. 2022. A model for sustainable adoption of solar photovoltaic technology in Tanzania. *Tanzania Journal of Engineering and Technology 2022*, 41(2), pp. 16-34. doi: 10.52339/tjet.v41i2.776.

Reindl, K. and Palm, J. 2021. Installing PV: Barriers and enablers experienced by non-residential property owners. *Renewable and Sustainable Energy Reviews*, 141, 110829. doi.org/10.1016/j.rser.2021.110829.

Rukshana, F., Darsono, S.N.A.C. and Suphanchaimat, N. 2020. Household solar photovoltaic adoption in the Maldives: A socioeconomic perspective. *Jurnal Ekonomi and Studi Pembangunan*, 21(2), pp. 185-198. doi: 10.18196/jesp.21.2.5040.

Sæle, H. and Cherry, T.I. 2017. Attitudes and perceptions about becoming a prosumer: results from a survey among Norwegian residential customers. *SINTEF Rapport*, 78. doi.hdl.handle.net/11250/2448126.

Saleem, S. and Zhang, Y. 2024. Impact of knowledge and trust on households' solar energy consumption behavior: Do social influence and gender matter? *Energy,* 293, 130719. doi:10.1016/j.energy.2024.130719.

Sanusi, Y.A. and Spahn, A. 2019. Exploring marginalization and exclusion in renewable energy development in Africa: A perspective from Western individualism and African Ubuntu philosophy. *Energy Justice Across Borders*, 273, pp. 273-296. doi.org/10.1007/978-3-030-24021-9.

Schultea, E., Schellera, F., Slootc, D. and Brucknera, T. 2022. A meta-analysis of residential PV adoption: the important role of perceived benefits, intentions and antecedents in solar energy acceptance. *Energy Research & Social Science,* 84, 102339. doi: 10.1016/j.erss.2021.102339.

Schwartz, S. H. 1994. Are there universal aspects in the structure and contents of human values? *Journal of Social Issues*, 50(4), pp. 19-45. doi.org/10.1111/j.1540-4560.1994.tb01196.x.

Schwartz, S.H. 2012. An overview of the Schwartz theory of basic values. *Online Readings in Psychology and Culture*, 2(1), 11. . doi.org/10.9707/2307-0919.1116.

Serra-Coch, G., Wyss, R. and Binder, C.R. 2023. Geographic network effects to engage people in the energy transition: The case of PV in Switzerland. *Heliyon,* 9(7), e17800. doi:10.1016/j.heliyon.2023.e17800.

SETO. 2021. 2030 solar cost target. Online Available: https://www.energy.gov/eere/solar/articles/2030-solar-cost-targets *(Accessed on 27 April 2023).*

Sguazzin, A. 2020. The world's biggest emitter of greenhouse gases. Online Available: https://www.bloomberg.com/news/features/2020-03-17/south-africa-living-near-the-world-s-biggest-emitting-plant. *(Accessed on 20 October 2024).*

Shakeel, S.R., Yousaf, H., Irfan, M. and Rajala, A. 2023. Solar PV adoption at household level: Insights based on a systematic literature review. *Energy Strategy Reviews*, 50, 101178. doi: org/10.1016/j.esr.2023.101178.

Shari, B.E., Madougou, S., Ohunakin, O.S., Blechinger, P., Moumouni, Y., Ahmed, A. and Tukur, Y. 2023. Exploring the dynamics of stakeholders' perspectives towards planning low-carbon energy transitions: a case of the Nigerian power sector. *International Journal of Sustainable Energy*, 42(1), pp. 209-235. doi.org/10.1080/14786451.2023.2186147.

Shimada, H. and Honda, T. 2022. What drives households' choices of residential solar photovoltaic capacity? *Energy Policy*, 168, 113120. doi: 10.1016/j.enpol.2022.113120.

Silva, C. and Guedes, I. 2023. The role of the media in the fear of crime: a qualitative study in the Portuguese context. *Criminal Justice Review*, 48(3), pp. 300-317. doi.org/10.1177/07340168221088570.

Smirnova, E., Kot, S., Kolpak, E. and Shestak, V. 2021. Governmental support and renewable energy production: A cross-country review. *Energy*, 230, 120903. doi.org/10.1016/j.energy.2021.120903.

Solar Energy UK. 2021. UK solar industry set to double in size by 2030 but needs to treble to align with net zero. Online Available: https://solarenergyuk.org/news/uk-solar-industry-set-to-double-in-size-by-2030-but-needs-to-treble-to-align-with-net-zero/. *(Accessed on 05 November 2024).*

Sonter, L.J., Dade, M.C., Watson, J.E. and Valenta, R.K. 2020. Renewable energy production will exacerbate mining threats to biodiversity. *Nature Communications*, 11(1), 4174. doi.org/10.1038/s41467-020-17928-5.

South African National Treasury. 2023. Frequently asked questions. Solar panel tax incentive for individuals Online Available: https://www.treasury.gov.za/documents/National%20Budget/2023/2023%20Budget%20FAQs%20-%20Solar%20Panel%20Tax%20Incentive.p. *(Accessed on 21May* 2023).

Sovacool, B.K, D'agostino A.L. and Bambawale, M.J. 2011. The socio-technical barriers to Solar Home Systems (SHS) in Papua New Guinea: choosing pigs, prostitutes, and poker chips over panels. *Energy Policy*, 39(3), pp. 1532-1542. doi: 10.1016/j.enpol.2010.12.027.

Sovacool, B.K., Baum, C.M. and Low, S. 2022. Determining our climate policy future: expert opinions about negative emissions and solar radiation management pathways. *Mitigation and Adaptation Strategies for Global Change,* 27(58), 58. doi.org/10.1007/s11027-022-10030-9.

Sovacool, B.K., Martiskainen, M., Hook, A. and Bake, L. 2019. Decarbonization and its discontents: a critical energy justice perspective on four low-carbon transitions. *Climate Change,* 155, pp. 581-619. doi: 10.1007/s10584-019-02521-7.

Sriwannawit, P. 2014. Transition towards off-grid photovoltaic systems: Is price the final answer? *Energy Procedia*, 57, pp. 1546-1554. doi.org/10.1016/j.egypro.2014.10.146.

Standard Bank. 2023. Standard Bank launches new low-interest solar loan solutions for homes and business. Online Available: https://www.standardbank.co.za/southafrica/news-and-media/newsroom/standard-bank-launches-new-low-interest-solar-loan-solutions-for-homes-and-business. *(Accessed on 23October 2024).*

State of Global Air. 2020. Global health impacts of air pollution. Online Available: http://www.stateofglobalair.org/health/global. *(Accessed on 27 February 2021).*

Statistics South Africa. 2018. Victims of crime report 2018/19. Online Available: www.statssa.gov.za/?m=2018. *(Accessed on 09 September 2024).*

Statistics South Africa. 2022. Census 2022. Online Available: http://www.statssa.gov.za/?page_id=3839 *(Accessed on 31 March 2024).*

Statistics South Africa. 2022. General Household Survey (GHS), 2021. Census Report 2021. Pretoria, Statistics South Africa. Online Available: statssa.gov.za. *(Accessed on 09 September 2024).*

Statistics South Africa. 2022. Quarterly labour force survey (QLFS) Q4: 2021 Pretoria: SA. Online Available: statssa.gov.za. *(Accessed on 09 September 2024).*

Statistics South Africa. 2024. Solar energy for the poor. Online Available: https://www.statssa.gov.za/?p=17167. *(Accessed on 06 September 2024).*

Steel, W.F., Anyidoho, N.A., Dadzie, F.Y. and Hosier, R.H. 20168. Developing rural markets for solar products: lessons from Ghana. *Energy for Sustainable Development*, 31, pp. 178-184. doi: 10.1016/j.esd.2016.02.003.

Stern, O.C., Dietz, T. and Vandenbergh, M.P. 2022. The science of mitigation: Closing the gap between potential and actual reduction of environmental threats. *Energy Research & Social Science*, 10, 102735. doi: 10.1016/j.erss.2022.102735.

Strauss, M. 2019. A historical exposition of spatial injustice and segregated urban settlement in South Africa. *Fundamina*, 25(2), pp. 135-168. doi.org/10.17159/2411-7870/2019/v25n2a6.

Sustainable Energy Africa. 2019. Modelling the financial case for rooftop solar PV in low- and mid-income households in South Africa. Online Available: https://www.sseg.org.za/wp-content/uploads/2019/10/Low-and-Mid-Income-Household-SSEG-Model-final-version-1.pdf

Szetela, B., Majewska, A., Jamroz, P., Djalilov, B. and Salahodjaev, R. 2022. Renewable energy and Co_2 emissions in top natural resource rents depending countries: The role of governance. *Frontiers in Energy Research*, 10, 872941. doi.org/10.3389/fenrg.2022.872941.

Tanaka, Y., Chapman, A., Sakurai, S. and Tezuka, T. 2017. Feed-in tariff pricing and social burden in Japan: Evaluating international learning through a policy transfer approach. *Social Sciences*, 6(4), 127. doi.org/10.3390/socsci6040127.

Tang, A., Alsultany, F. H., Borisov, V., Mohebihafshejani, A., Goli, A., Mostafaeipour, A. and Riahi, R. 2022. Technical, environmental and ranking analysis of using solar heating: A case study in South Africa. *Sustainable Energy Technologies and Assessments*, 52, 102299. doi.org/10.1016/j.seta.2022.102299.

Tawalbeh, M., Al-Othman, A., Kafiah, F., Abdelsalam, E., Almomani, F. and Alkasrawi, M. 2021. Environmental impacts of solar photovoltaic systems: A critical review of recent progress and outlook. *Science of The Total Environment*, 759, 143528. doi: 10.1016/j.scitotenv.2020.143528.

Thiam, D.R. 2011. An energy pricing scheme for the diffusion of decentralized renewable technology investment in developing countries. *Energy Policy*, 39(7), pp. 4284-4297. doi:10.1016/j.enpol.2011.04.046.

Thobejane, J., Masekameni, D., Rathebe, P. and Mgwambani, S.L. 2019. The effectiveness of solar water heating geysers in South Africa: A Review. *2019 International Conference on the Domestic Use of Energy (DUE)*, pp. 59-62. Online Available: https://www.researchgate.net/publication/333894977. *(Accessed on 10 April 2023).*

Thompson, C. 2020). *Solar Panel Installation: How to Install Solar Step by Step*. Unbound Solar. Online Available: https://unboundsolar.com/blog/step-by-step-diy-solar-installation. *(Accessed on 09 September 2024).*

TIBCO Software Inc. 2019. Statistica (data analysis software system), version 14. Online Available: http://tibco.com. *(Accessed on 19 June, 2024)*.

Tlhatlha, P.V. 2020. Renewable energy strategies for alleviating energy poverty in informal settlements: A case study of Diepsloot-South Africa. [Master of Science thesis University of Pretoria South Africa].

Ugulu, A.I. 2019. Barriers and motivations for solar photovoltaic (PV) adoption in urban Nigeria. *International Journal of Sustainable Energy Planning and Management*, 21, pp. 19-34. doi.org/10.5278/ijsepm.2019.21.3.

Uğur-Kılıç, U. and Kekezoğlu, B. 2022. A review of solar photovoltaic incentives and Policy: Selected countries and Turkey. *Ain Shams Engineering Journal*, 13(5), 101669. doi.org/10.1016/j.asej.2021.101669.

Ukoba, K., Yoro, K.K., Eterigho-Ikelegbe, O., Ibegbulam, C. and Jen, T. 2024. Adaptation of solar energy in the Global South: Prospects, challenges and opportunities. *Heliyon*,10(7), e28009. doi.org/10.1016/j.heliyon.2024.e28009.

Unbound solar. 2020. Solar panel installation: How to install solar step by step. Online Available: https://unboundsolar.com/blog/step-by-step-diy-solar-installation#planning-and-safety. *(Accessed on 10 April 2023).*

UNDP.2020. Mini-Grids for Powering and Developing the Rural Sahel. Online Available: https://www.undp.org/africa/waca/blog/mini-grids-powering-and-developing-rural-sahel. *(Accessed on 04 October 2024)*

United Nations, 2023. The true costs of conventional energy Online Available: https://www.un.org/en/chronicle/article/true-costs-conventional-energy. *(Accessed on 10 April 2023).*

United States Environmental Protection Agency. 2024. Energy and environment guide to action - Chapter 5: Renewable Portfolio Standards. Online Available: https://www.epa.gov/statelocalenergy/energy-and-environment-guide-action-chapter-5-renewable-portfolio-standards. *(Accessed on 26 July 2024).*

US Department of Energy. 2022. Best practices guide for inclusive solar energy communications. Online Available: https://www.energy.gov/eere/solar/best-practices-guide-inclusive-solar-energy-communications. *(Accessed on 10 April 2023).*

Van Norden, S. 2015. Investigation of the barriers for the diffusion of photovoltaic systems in Cape Town. [Master of Science Thesis. Sweden, Stockholm University].

Vasseur, V. and Kemp, R. 2015. The adoption of PV in the Netherlands: A statistical analysis of adoption factors. *Renewable and Sustainable Energy Reviews*, 41, pp.483-494. doi: 10.1016/j.rser.2014.08.020.

Vasseur, V. and Kamp, L.M. 2013. A comparative analysis of photovoltaic technological innovation systems including international dimensions: the cases of Japan and the Netherlands. *Journal of Cleaner Production*, 48, pp. 200-210. doi:10.1016/j.jclepro.2013.01.017.

Victoria, M., Haegel, N., Marius Peters, I., Sinton, R., Jäger-Waldau, R., del Cañizo, C., Breyer, C., Stocks, M., Blakers, M., Kaizuka, I., Komoto, K. and Smets, A. 2021. Solar photovoltaics is ready to power a sustainable future. *Joule*, 5(5), pp. 1041-1056. doi.org/10.1016/j.joule.2021.03.005.

Viljoen, G. and Dube, F. 2023. Realising the right to electricity through off-grid power solutions in South Africa. *Potchefstroom Electronic Law Journal (PELJ)*, 26(1), pp. 1-25. doi.org/10.17159/1727-3781/2023/V26I0A15637.

Walters, J., Kaminsky, J. and Gottschamer, L. 2018. A systems analysis of factors influencing household solar PV adoption in Santiago, Chile. *Sustainability*, 10(4), pp. 1257-1277. doi.org/10.3390/su10041257.

Wang, C., Wang, Y., Zhao, Y., Shuai, J., Shuai, C. and Cheng, X. 2023. Cognition process and influencing factors of rural residents' adoption willingness for solar PV poverty alleviation projects: Evidence from a mixed methodology in rural China. *Energy*, 271, 127078. doi.org/10.1016/j.energy.2023.127078.

Wang, X. and Lo, K. 2021. Just transition: A conceptual review. *Energy Research & Social Science*, 82. 102291. doi.org/10.1016/j.erss.2021.102291.

Wolske, K.S, Stern, P.C. and Dietz, T. 2017. Explaining interest in adopting residential solar photovoltaic systems in the United States: toward an integration of behavioral theories. *Energy Research and Social Science*, 25, pp. 134-151. doi.org/10.1016/j.erss.2016.12.023.

World Bank. 2019. Electrification efforts in sub-Saharan Africa must address root causes of low access. Online Available: http:// https://www.worldbank.org. *(Accessed on 27 March 2022).*

World Bank. 2019. Mini grids for half a billion people: market outlook and handbook for decision makers. Online Available: https://www.undp.org/africa/waca/. *(Accessed on 04 October 2024).*

World Bank. 2024. The World Bank in South Africa. Online Available: https://www.worldbank.org/en/country/southafrica/overview. *(Accessed on 06 May 2024).*

World Nuclear Association. 2024. Carbon dioxide emissions from electricity. Online Available: https://world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity. *(Accessed on 22 May 2024).*

Wüstenhagen, R. and Menichetti, E. 2012. Strategic choices for renewable energy investment: conceptual framework and opportunities for further research. *Energy Policy,* 40, pp. 1-10. doi.org/10.1016/j.enpol.2011.06.050.

Xue, L., Haseeb, M., Mamood, H., Alkhateeb, T. and Murshed, M. 2021. Renewable energy use and ecological footprints mitigation: Evidence from selected South Asian economies. *Sustainability,* 13. 1613. doi.org/10.3390/su13041613.

Yang, C., Nutakki, T.U.K., Alghassab, M.A., Alkhalaf, S., Alturise, F., Alharbi, F.S., Elmasry, Y. and Abdullaev, S. 2024. Optimized integration of solar energy and liquefied natural gas regasification for sustainable urban development: Dynamic modeling, data-driven optimization, and case study. *Journal of Cleaner Production*, 447(2), 141405. doi: 10.1016/j.jclepro.2024.141405.

Yao, H. and Zhou, Q. 2023. Research status and application of rooftop photovoltaic generation systems. *Cleaner Energy Systems*, 5, 100065. doi.org/10.1016/j.cles.2023.100065.

Yuan, X. Zuo, J. and Ma, C. 2011. Social acceptance of solar energy technologies in China. End users' perspective. *Energy Policy*, 39(3), pp. 1031-1036.doi.org/ 10.1016/j.enpol.2011.01.003.

Zhang, R., Yin, L., Jia, J. and Yin, Y. 2019. Application of ATS-GWIFBM operator based on improved time entropy in green building projects. *Advances in Civil Engineering*, *2019*(1), . 3519195. doi.org/10.1155/2019/3519195.

Zhang, S. and He, Y. 2013. Analysis on the development and policy of solar PV power in China. *Renewable and Sustainable Energy Revolution*, 21, pp. 393-401. doi: 10.1016/j.rser.2013.01.002.

Appendix 2.1: List of the 18 reviewed papers on the adoption of rooftop solar PV systems in South Africa

1. Adams, S.L. 2012. South African consumer attitudes towards domestic solar power systems [Dissertation, University of Pretoria]. https://repository.up.ac.za/handle/2263/24826.
2. Aigbavboa, C. 2015. Low-income housing residents' challenges with their government install solar water heaters: A case of South Africa. Energy Procedia, 75, pp. 495-501. doi.org/10.1016/j.egypro.2015.07.437.
3. Azimoh, C.L., Klintenberg, P., Wallin, F. and Karlsson, B. 2015. Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa. *Applied energy*, *155*, pp.354-364. doi.org/10.1016/j.apenergy.2015.05.120.
4. Azimoh, C.L., Wallin, F., Klintenberg, P., and Karlsson, B. 2014. An assessment of unforeseen losses resulting from inappropriate use of solar home systems in South Africa. *Applied Energy*, *136*, 336-346. doi.org/10.1016/j.apenergy.2014.09.044.
5. Bikam, P. and Mulaudzi, D.J. 2006. Solar energy trial in Folovhodwe South Africa: Lessons for policy and decision-makers. *Renewable Energy,* (31)10, pp. 1561-1571. doi.org/10.1016/j.renene.2005.07.015.
6. Chang, K.C., Lin, W.M., Ross, G. and Chung, K.M. 2011. Dissemination of solar water heaters in South Africa. *Journal of Energy in Southern Africa*, 22(3), pp. 2-7. doi: 10.17159/2413-3051/2011/v22i3a3216.
7. Chidembo, R., Francis, J. and Kativhu, S. 2022a. Rural households' perceptions of the adoption of rooftop solar photovoltaics in Vhembe district, South Africa. *Energies*, *15*(17). doi.org/10.3390/en15176157.
8. Chidembo, R., Francis, J. and Kativhu, S. 2022b. A Review of the achievements, weaknesses, and challenges of rural electrification through solar home systems in South Africa. *African Journal of Development Studies (Formerly AFFRIKA Journal of Politics, Economics and Society)*, 2, pp. 191-211. doi.org/10.31920/2634-3649/2022/sin1a9.
9. Conway, D., Robinson, B., Mudimu, P., Chitekwe, T., Koranteng, K. and Swilling, M. 2019. Exploring hybrid models for universal access to basic solar energy services in informal settlements: Case studies from South Africa and Zimbabwe. *Energy Research and Social Science*, *56*. doi.org/10.1016/j.erss.2019.05.012.

10. Curry, C., Cherni, J.A., and Mapako, M. 2017. The potential and reality of the solar water heater programme in South African townships: Lessons from the City of Tshwane. *Energy Policy*, 106, 75-84. doi.org/10.1016/j.enpol.2017.03.028.
11. Donev, G., van Sark, W.G. J.H.M., Blok, K. and Dintchev, O. 2012. Solar water heating potential in South Africa in dynamic energy market conditions. *Renewable and Sustainable Energy Reviews*, 16(5), 3002-3013. doi.org/10.1016/j.rser.2012.01.065.
12. Hendricks, D. 2016. Factors influencing adoption of PV technology as an alternative energy in households: A case of Parkhurst, South Africa. [Dissertation, University of Pretoria, Gordon Institute of Business Science]. https://repository.up.ac.za/handle/2263/24826.
13. Lemaire, X. 2011. Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. *Energy for Sustainable Development*, *15*(3), 277-283. doi.org/10.1016/j.esd.2011.07.005.
14. McKay, T. and Hendricks, D. 2022. Pitiful rooftop solar uptake in sunny South Africa: A policy, funding and service delivery perspective. *Frontier in Sustainable Cities*, 4. doi.org/10.3389/frsc.2022.969040.
15. Mulaudzi, S.K., Bull, S. and Makhado, R.A. 2022. Potential of households' solar PV consumption in South Africa. *African Journal of Science, Technology, Innovation and Development*, 14(3), pp. 730-739. doi: 10.1080/20421338.2021.1894728.
16. Tang, A., Alsultany, F. H., Borisov, V., Mohebihafshejani, A., Goli, A., Mostafaeipour, A. and Riahi, R. 2022. Technical, environmental and ranking analysis of using solar heating: A case study in South Africa. *Sustainable Energy Technologies and Assessments*, 52. doi.org/10.1016/j.seta.2022.102299.
17. Thobejane, J., Masekameni, D., Rathebe, P. and Mgwambani, S.L. 2019. The effectiveness of solar water heating geysers in South Africa: A Review. Online Available: https://www.researchgate.net/publication/333894977. *(Accessed on 10 April 2023).*
18. Tlhatlha, P.V. 2020. Renewable energy strategies for alleviating energy poverty in informal settlements: A case study of Diepsloot-South Africa. [Master of Science thesis, University of Pretoria].

Appendix 3.1: Non-adopters' interview guide

Determinants, barriers, and enablers of solar adoption among South African households

Questionnaire no: ________ Date: __________ Field worker name: ____________________

Town: _________________________ Neighbourhood: Township [ ] RDP [ ] Affluent [ ]

Random sample point no.__________________________

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SECTION A: SOLAR ADOPTION AMONG HOUSEHOLDS

1. Why do you not to have solar PV for your household?
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2. Have you ever considered adopting solar energy for your home and if so, give reasons?
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3. In the last 10 years, when did you start seriously considering to adopt solar energy at your household?
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4. Out of the said factors, which one do you rank first and why?
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5. What do you know about how solar energy works and how it can be stored?
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6. If respondent has some knowledge – where does s/he get the information?
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7. In the last six months, did you receive any form of advertisement from companies that install solar panels? (Explain your answer)
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8. The market value of property is determined by the facilities it offers. Can you say, solar panels could increase your property value? (Explain)
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9. Do you feel that the government (favorable policy instruments) might support your decision to purchase solar for your household?

Yes [ ] No [ ]

Please explain

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10. Excess solar energy can be fed into the national grid. In the event you generate excess energy, how easy do you think it is to supply to the national grid

Very easy [ ] Easy [ ] Not sure [ ] Difficult [ ] Very difficult [ ]

Please explain your response

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SECTION B: (COGNITIVE FACTORS) KNOWLEDGE OF SOLAR ENERGY

11. Solar energy can be stored for use during low generation capacity. In your view do you think you have sufficient information on storage of solar power?

Yes [ ] No [ ]

Explain your answer

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12. Would you say you have sufficient information on solar generation capacity needed to support the energy needs of your household?

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13. In your view, do you think that solar energy can provide you with a cheaper alternative than Eskom? (Explain your answer)

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14. In your view, do you think that using solar could protect your family from rolling electricity blackouts? (Explain your answer)

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Please, indicate your level of agreement with the following factors on solar energy:

Riskiness

		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
15.	I would worry about having solar energy because it would be an unfamiliar experience.					
16.	I would worry about having solar energy because they would be expensive to maintain.					

17.	I would worry about having solar energy because it attracts taxes from the government.					
18.	I would worry about having solar energy because I do not have rooftop space to install it.					
19.	Installation of solar panels will negatively affect the appearance of my roof (aesthetics).					
20.	I am worried that install solar energy, the solar panels might be stolen .					
21.	I would worry about having solar energy because it is affected by weather (rain, clouds, seasons)					

Environmental benefits

	Description	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
22.	Solar energy helps slow down climate change.					
23.	If more households adopt solar energy, environmental impacts will be reduced (less air, land and water pollution, less land degradation from coal mining)					
24.	Transitioning to solar energy would be a good to reduce my environmental impact					

SECTION C: RESPONDENT SOCIAL FACTORS AND VALUES

25. Here we would like you to rate the importance of the following life values to you:

[1= Unimportant; 2= Slightly important; 3 = Important; 4 = Very important; 5 = Critical]

Description	Unimportant	Slightly important	Important	Very important	Critical
Authority: the right to lead or command					
Social power: control over others; dominance					
Wealth: material possessions, money					
Influence: having an impact on people and events					
Social justice: correcting injustice, caring for the weak					
Helpful: working for the welfare of others					
Equality: equal opportunity for all					
A world at peace: free of war and conflict					
Protecting the environment: preserving nature					
Preventing pollution of land, air or water					
Respecting the earth: live in harmony with other species					
Unity with nature: fitting into nature					

Social influences

	Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
26.	Most people who are important to me would support the adopt solar energy					
27.	People who are important to me would be in favour of installing solar panels.					
28.	My family members would be opposed to getting solar panels.					

SECTION D: RESPONDENT PROFILE

29. How long have you lived in this town? ______________________

30. What year were you born? _______________________

31. What is your highest level of education? ______________________

32. How many people live in your household? ______________________

33. What is your home language? isiXhosa [ ] isiZulu [ ] Afrikaans [ ]
English [ ] Other [ ]

34. Gender? Female [ ] Male [ ] Non-binary [ ]

35. What is the biggest source of your ***household*** income?
Wages [ ] Social grants [ ] Private pensions [ ] Own business [ ]

36. Pls indicate the broad range of the ***household*** monthly income (Rands)
<2,000 [ ] 2,001 – 6,000 [ ] 6,001 – 15,000 [ ] 15,0001 – 30,000 [ ] > 30,000 [ ]

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END OF SURVEY

THANK YOU VERY MUCH

DO YOU HAVE ANY QUESTIONS FOR US?

Appendix 4.1: Adopters interview guide

DETERMINANTS, BARRIERS AND ENABLERS OF SOLAR ADOPTION AMONG SOUTH AFRICAN HOUSEHOLDS

Questionnaire no: ________ Date: __________ Field worker name: ____________________

Town: _________________________ Neighbourhood: Township [ ] RDP [ ] Affluent [ ]

Random sample point no.__________________________

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SECTION A: SOLAR ADOPTION AMONG HOUSEHOLDS

37. What are the factors that motivated you to adopt solar energy?
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38. Out of the said factors, which one do you rank first?
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39. When was the solar system installed?
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40. Solar installation was A private installation [ ] Part of a programme [ ] A government initiative [ ]

41. What do you use solar for? Tick the appropriate answer

Heating (including geyser),

Lighting

Cooking

Cooling

Entertainment

42. Overall, how satisfied are you with your solar system?

Very satisfied [ ] Satisfied [ ] Neutral [ ] Dissatisfied [ ] Very dissatisfied [ ]

43. In your opinion, do you feel you had enough information to adopt solar as an energy source in the household? (Please explain your answer)

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44. Where did you get this information?

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45. Government policies can support the shift to solar energy adoption. Do you feel that the government (favorable policy instruments) has supported your decision to adopt solar?

Yes [ ] No [ ]

Please explain

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46. Excess solar energy can be fed into the national grid. In the event you generate excess energy, how easy is it to supply to the national grid

    Very easy [ ]   Easy [ ]   Not sure [ ]   Difficult [ ]   Very difficult [ ]

    Please explain your response

    ....
    ....
    ....
    ....
    ....

SECTION B: (COGNITIVE FACTORS) KNOWLEDGE OF SOLAR ENERGY

47. Solar energy can be stored for use during low generation capacity. In your view/experience, do you think you have sufficient information on storage?

    Yes [ ]   No [ ]

    Explain your answer

    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ………………………

48. Relative to Eskom power, how dependable is solar energy?

    Very dependable [ ]   Partially dependable [ ]   Not dependable [ ]

    Explain your answer

    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ……………………….

49. Would you say you have information on solar generating capacity needed to support energy needs in the household?

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50. Overall, do you think that solar energy has provided you with a cheaper alternative than Eskom? (Please explain your answer)

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51. In your view, can you say solar has cushioned your family from rolling electricity blackouts? (Please explain your answer)

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………………………

Please, indicate your level of agreement with the following factors on solar energy:

Riskiness

		Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
52.	I am worried about having solar energy because it is an unfamiliar experience.					
53.	I am worried about having solar energy					

	because it is expensive to maintain.					
54.	I am worried about having solar panels because it attracts taxes from the government.					
55.	Installing solar panels have negatively affected the appearance of my roof (aesthetics)					
56.	I am worried about having solar panels because they are installed outside the house.					
57.	I am worried about having solar panels because it is affected by weather (rain, clouds, seasons).					

Environmental benefits

	Description	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
58.	Solar energy helps slow down climate change.					
59.	If more households adopt solar panels, environmental impacts will be reduced (less air pollution, less land degradation resulting from coal mining, less water pollution).					
60.	Transitioning to solar energy is a good way to reduce my environmental impact					

SECTION C: RESPONDENT SOCIAL FACTORS AND VALUES

61. Here we would like you to rate the importance of the following 12 values to you:

[1= Unimportant; 2= Slightly important; 3 = Important; 4 = Very important; 5 = Critical]

Description	Unimportant	Slightly important	Important	Very important	Critical
Authority: the right to lead or command					
Social power: control over others; dominance					
Wealth: material possessions, money					
Influence: having an impact on people and events					
Social justice: correcting injustice, care for the vulnerable					
Helpful: working for the welfare of others					
Equality: equal opportunity for all					
A world at peace: free of war and conflict					
Protecting the environment: preserving nature					
Preventing pollution of land, air or water					
Respecting the earth: live in harmony with other species					
Unity with nature: fitting into nature					

Social influences

	Description	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
62.	Most people who are important to me have supported my decision to adopt solar energy					
63.	People who are important to me have favoured the installation of solar energy.					
64.	My family members have opposed the idea of getting solar energy.					

SECTION D: RESPONDENT PROFILE

65. How long have you lived in this town? ______________________

66. What year were you born? ______________________

67. What is your highest level of education? ______________________

68. How many people live in your household? ______________________

69. What is your home language? isiXhosa [ ] isiZulu [ ] Afrikaans [ ]
English [ ] Other [ ]

70. Gender? Female [ ] Male [ ] Non-binary [ ]

71. What is the biggest source of your ***household*** income?
Wages [ ] Social grants [ ] Private pensions [ ] Own business [ ]

72. Pls indicate the broad range of the ***household*** monthly income (Rands)
<2,000 [ ] 2,001 – 6,000 [ ] 6,001 – 15,000 [ ] 15,0001 – 30,000 [ ] >
30,000 [ ]

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END OF SURVEY

THANK YOU VERY MUC

Appendix 5.1: Key informant interview guide

Org code (if relevant)	Date (dd/mm/yy)	Interview number

To be completed by the interviewer

1. Introduction

This interview aims to identify the main barriers and enablers of solar energy adoption in South African households. It will focus on the experts view on (solar) renewable energy policy in South Africa. These include, but not limited to: Energy service providers; solar PV distributors; Academic institutions; municipalities

READ THE INFORMED CONSENT FORM TO THE RESPONDENT(S) AND ASK THEM TO SIGN IT.

1.1 What is your current position? (WRITE THE RESPONSE BELOW)

1.2 What is your current place of work or institution? (WRITE THE RESPONSE BELOW)

1.3 Are you a representative of ....: (READ THE RESPONSES BELOW AND CHECK ALL THAT APPLY)

1. The Department of Energy
2. Eskom
3. A solar PV retailer/distributor
4. A member of the regulatory body,
5. An independent power producer
6. An academic
7. A member of the municipality
8. Other (SPECIFY):

2. Households

2.1 In your opinion, what attracts households to consider adopting solar PV as an energy source? (CHECK ALL THAT APPLY)

- ☐ 1. Quality output
- ☐ 2. Strong intentions to move to solar energy
- ☐ 3. Perceived usefulness of solar PV in the household
- ☐ 4. Perceived ease of solar PV use in the household
- ☐ 5. Concern about the environment
- ☐ 6. Subjective Norms- societal expectations/family influence
- ☐ 7. Job relevance- the perceived relevance of solar PV in the household
- ☐ 8. Attractive long-term compensation
- ☐ 9. Favorable government/renewable energy policies
- ☐ 10. They have no other choice
- ☐ 11. Image- adopting solar PV is viewed as prestigious
- ☐ 12. Other (SPECIFY): ______

2.2 In relation to your previous response, what is the single most important factor that attracts households to move to solar PV as a source of energy?

______

2.3 In your opinion, do households have the required knowledge/information that can prepare them to adopt solar PV as a source of energy? (CHECK ONE ANSWER)

- ☐ 1. Yes
- ☐ 2. No
- ☐ 3. I don't know

2.3.1 Why? Explain your answer.

______

3. Policies

3.1 In your opinion do you think that government policies have got an influence on the transition to solar PV among South African households?

- ☐ 1. Yes
- ☐ 2. No
- ☐ 3. I don't know

3.1.1 Why? Explain your answer.

3.2 In your opinion, do you think that South Africa has policies that support the transition to solar PV among households? (CHECK ONE ANSWER)

4. Yes
5. No
6. I don't know

3.2.1 Why? Explain your answer.

3.3 If your answer is yes above, how effective are these policies in facilitating a transition to solar PV among households in South Africa?

3.4 In your opinion, what steps should be taken to ensure that more households adopt solar PV as a form of energy in South Africa? (CHECK ALL THAT APPLY)

1. Decrease feed in tariffs
2. Increase number of solar PV suppliers/retailers
3. Educating households on the potential of solar PV
4. Increase access to bank loans
5. Train more solar PV technicians who can install solar PV systems
6. Other (SPECIFY):

3.5 Does the government have a policy that supports independent power producers (CHECK ONE ANSWER)

1. Yes
2. No
3. I don't know

3.6 What opportunities are available in the country for Independent power producers to keep their knowledge and skills up-to-date? (CHECK ALL THAT APPLY)

1. Conferences and professional forums

- [ ] 2. Workshops
- [ ] 3. Training offered by professional associations
- [ ] 4. In-service training courses offered by nongovernmental organizations and development partners
- [ ] 5. I don't know
- [ ] 6. Other (SPECIFY): ______

3.7 In your opinion, do you think that Eskom's monopoly in the energy industry has got an impact on solar PV adoption among households? (CHECK ONE ANSWER)

- [ ] 1. Yes
- [ ] 2. No
- [ ] 3. I don't know

3.7.1 If yes, what steps could be taken to improve this scenario?

4 We have reached the end of our interview. Do you have any additional suggestions for the adoption of solar PV among households in the country?

Thank you!