A Systematic Review and Meta-Analysis of Solar Technology Impacts on Rural Households: Experiences from The Global South.

by

DEANNTHA KANNIAH

215006074

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SUPERVISOR: Dr. S. MUNIEN

Signed: [redacted] Name: Dr. S. MUNIEN Date: 13 October 2021

PREFACE

The work described in this thesis was carried out in the School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal, Westville campus, from April 2019 to August 2021, under the supervision of Dr Suveshnee Munien. This study represents original work by Deanntha Kanniah and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

DECLARATION -PLAGIARISM

I, Deanntha Kanniah declare that:

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ABSTRACT

Renewable energy technologies are widely prescribed to address multiple developmental needs, especially in developing contexts. As reflected in the growing body of literature, these devices and energy sources can generate socio-economic and environmental benefits and offer relatively rapid transitions to more sustainable practices. In this regard, it is essential to understand and identify the links among their impacts at a household and community level. This study aimed to critically examine how the impacts of solar technologies have been examined and measured at the household level, focusing on low-income and rural communities across the Global South. This review systematically focuses on research within a specified temporal range, 1999 to 2019, concerning the UNDG's definition of impact and the sustainable livelihood's theoretical framework. The motivation for this review is to establish whether research of the developing contexts have been able to respond to the multi-dimensionality of energy access and determine whether research has been a reflection of the changing energy narratives on energy needs. In addition, this review examines how and whether the impacts of solar energy technologies (SETs) are examined in relation to specific livelihood outcomes. Following the PRISMA 2009 and 2020 guideline for systematic reviews, the Web of Science, Google Scholar, and WorldCat databases were used. The initial search yielded (n=175187), which was later reduced to a total of n=56 cases that met the geographic, temporal, and content-related criteria. It was found that over the temporal range, Global South countries contributed a significantly lower number of published research compared to the global north countries. Over time, progressive trends in the proportion, dissemination and development of different SET's could be identified as literature was found to have investigated several types of SETs across 24 different Global South countries using eight different analyses dominated by mixed-method approaches and field survey methods. The meta-analysis revealed that despite the diversity in indicators, no studies reported against all capital bases of rural livelihoods. In addition, the classification identified that there were more qualitative and indirect measures of SET impact at the household level. Despite financial indicators appearing in all the reviewed studies, the diversity and inclusivity of the indicators used were reflected in the increasing proportion with which other livelihood impacts were recorded over the temporal range. From the analysis of mean impacts, the overall impression given is that SET's have a positive impact on the livelihoods rural households in developing countries. However, the proportion of studies using each indicator is insufficient for these impacts to be definitive due to the variation. The review concludes that the impacts of solar technologies at the household level in developing contexts are not specific to livelihoods benefits in how they are reported. This makes it difficult

to assess the overall successes of RET- transfer in the domestic sector. A recommendation based on this review is to use mixed method approaches, more diverse indicators and the SLA and UNDG's definition of impact. This would ensure that future impact analyses are a true reflection of all possible impacts of SET's on rural households and the selection of the most appropriate SET's to be installed in rural households. There should be significant efforts to bring together academia, industry, and government to facilitate and encourage further research and expand SET's across more developing countries to promote development and innovation within the industry. Lastly, to ensure that SET's have a sustainable impact on rural households the operation and maintenance of SET's needs to increase.

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LIST OF ABBREVIATIONS

BRICS	Brazil, Russia, India and South-Africa
CBA	Cost-Benefit Analysis
CSP	Concentrating Solar Power
DAC	Development Assistance Committee
DFID	Department for International Development
DOE	Department of Energy
ESRI	Environmental Systems Research Institute
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
HDI	Human Development Index
IEA	International Energy Agency
LCA	Life-cycle Analysis
LPG	Liquefied Petroleum Gas
MDG's	Millennium Development Goals
MW	Megawatt
OECD	Organisation for Economic Co-operation and Development
PRISMA	Preferred Reporting Items for Systematic Review
PV	Photovoltaic
RESURL	Renewable Energy for Sustainable Rural Development
RET	Renewable Energy Technology
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SET's	Solar Energy Technologies
SHS	Solar Home System
SLA	Sustainable Livelihoods Approach
SLF	Sustainable Livelihoods Framework
SPSS	Statistical Packages for Social Sciences.
SWH	Solar Water Heaters

TV	Television
UKZN	University of KwaZulu-Natal
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDG	United Nations Development Group
UNDP	United Nation Development Plan
USD	United States Dollar
WHO	World Health Organisation
WSSD	World Summit on Sustainable Development

CHAPTER ONE
INTRODUCTION

1.1 Background

Over one billion people across the globe lack access to essential energy services, 97% of whom live in sub-Saharan Africa and South-East Asia located in the Global South (Yadav et al., 2019). At present, 85% of the unelectrified households on these continents are rural and low-income communities (Mbaka et al., 2018). According to Chen et al. (2017), geographic isolation, low unemployment rates and the lack of income, infrastructure and resources confound transmission losses, rendering energy-grid extensions economically unfeasible. These factors provide insight into the barriers faced by developing countries in addressing the dual challenge of improving energy access and transitioning to the needs of people who lack access to energy services while joining in on the global transition to the use of sustainable and low-carbon energy systems. Nonetheless, the importance of accessing suitable, safe, reliable, and cost-effective energy is undisputed in improving the overall quality of life and socio-economic well-being (Munien, 2016; Nadimi, 2019). More importantly, there is an increasing awareness of the multidimensional benefits leveraged due to access to improved energy services (Kowalska-Pyzalska, 2018)). Despite indirect links to energy in most Millennium Development Goals (MDG's), McCollum et al. (2018) highlight that the MDG's did not refer to energy specifically. However, the Sustainable Development Goals, goal 7 (SDG7), specifically calls for action to ensure access to clean, affordable, and reliable energy for all.

Evidently, these shifts in policy and energy planning seeks to provide more robust attempts at addressing energy poverty as there is substantial work that needs to be done. For example, in Nepal, many impoverished rural communities spend more than one-third of their household expenditure on energy services (Sapkota et al., 2014). A closer inspection reveals the gender and geographic nuances that are associated with lack of access to modern, safe, reliable, and cost-effective energy sources and services. Sapkota et al. (2014) show that women and young girls spend more than 6 hours a day collecting wood and water. In Africa the number of people using fuelwood will increase by 40% to approximately 700 million people in Africa by 2030. This scenario signifies possible threats to livelihood sustainability and the need for an off-grid solution like solar energy technologies (SET's) that can even be used in remote areas that are not connected to the grid. Fortunately, there has been rapid and substantial development in the renewable energy sector where solar energy capacity grew, accounting for nearly 55% of newly installed renewable power capacity (Renewables, 2017). Furthermore, according to the International Energy Agency's (IEA) Renewables 2019 report, there has been a surge in the adoption of SETs in developed countries and developing countries. For example, the increase in SET uptake began notably in Bangladesh and Kenya and in South Africa and Brazil (IEA, 2017). Solar Photovoltaic (PV) systems and solar water heaters (SWH) are some of the more commonly used SETs that developing nations are investing in through national programmes (Urban et al., 2016; Mondol and Klein, 2011; Wlokas, 2011). In South Africa, the National SWH programme was initiated by the country's national power utility, ESKOM (Curry et al., 2017). The programme aimed to achieve the installation of one million SWH in households across the country by 2014 through a rebate scheme to phase out the use of electric geysers and encourage the use of solar water heaters in order to reduce the demand on the national grid (Curry et al.,2017). In 2014, 40000 SWH were installed by 2014 compelling the Department of Energy (DOE) to take over and change the aim to providing solar water heaters to government aided and unelectrified homes, in addition to setting a new target of 1.75 million units by 2019, and five million by 2030 (Kretzmann, 2018).

The prescribed new targets coincide with the transition from the MDG's to SDG's in 2015 and the United Nations (UN's) declaration that 2014–2024 be the Decade of Sustainable Energy for All (SE4ALL), encouraging governments to renew their commitments toward this goal, which has resulted in the increased dissemination of SETs at the household level. The narrative changed from providing energy access to looking at poverty in its entirety and addressing the energy needs of households (Schuller and Levey, 2018). This led to numerous studies being undertaken to evaluate the impact these technologies have on the households that use them. Impact studies are commonly associated with investigating the effectiveness of policy but, over time, has proved a useful tool and applies to all areas of life as an approach to gathering evidence that reveals whether and how an intervention is responsible for changes (Streatfield and Markless, 2009). Consequently, impact indicators are becoming increasingly multi-dimensional, thus extending the scope of how impacts are viewed and measured. In this regard, some definitions may emphasise specific understandings of impact, but others evolved to include aspects of well-being and sustainable growth (Hearn, 2016). However, how impact is defined has a significant influence over the design and evaluation of the technology that is being investigated.

According to the Organisation for Economic Co-operation and Development – Development Assistance Committee (OECD-DAC, 2002:24), impact is defined as:

> 'Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended.'

Similarly, the Global Environment Facility (GEF, 2009:5) define impact as:

> "…a fundamental and durable change in the condition of people and their environment brought about by the project."

While the United Nations Development Group (UNDG, 2011:7) highlight that:

> "Impact implies changes in people's lives. This might include changes in knowledge, skill, behaviour, health or living conditions for children, adults, families or communities. Such changes are positive or negative long-term effects on identifiable population groups produced by a development intervention, directly or indirectly, intended or unintended. These effects can be economic, socio-cultural, institutional, environmental, technological or of other types."

As mentioned, these definitions highlight multi-dimensions that are unpacked when examining impacts. The UNDG's (2011) definition of impact is different from previous definitions in that it includes aspects that specify areas in which these changes can take place and whom the changes might affect. This definition not only acknowledges that the impact can be positive or negative intended or accidental but underscores multiple classifications that may exist for specific types of impact. Furthermore, determining the impact of energy technologies at the household level has been done through various methods that range from cost-benefit analyses (Sadiq, 2017), energy expenditure models (Pinchot et al., 2013), and more recently, comparative assessments of energy practices pre-and post-installation (Curry et al., 2017; Naspolini and Ruther, 2017; Sharma at al., 2019). According to the OECD (2014), impact assessments focus on the effects of the intervention, whereas evaluation is expected to address an extensive range of issues such as intervention design, suitability rate and efficiency, and user experience. These definitions of impact suggest that irrespective of whether an assessment or evaluation is done, there is a need to be holistic when examining impacts. Although the UNDG's definition precedes the SDGs, it bears a significant relation to the aims and objectives hoped to be achieved by them.

This study uses these definitions and underpinnings to systematically unpack the nature of SET impacts and how these are measured and documented in the developing context. Furthermore, drawing from the more nuanced understanding of the importance of securing energy access to reliable, sustainable and cost-effective energy sources for socio-economic development, this study uses the Sustainable Livelihoods Approach (SLA) to examine which aspects of livelihoods are being affected by SETs in particular. The SLA provides a framework for researchers to understand these impacts at the household level and serves as an analytical tool that shows how these households secure and maintain their livelihoods (Elizondo, 2017). This is important because the introduction of technological assets such as SET can be a critical enabling asset that influences the livelihood strategies of many rural households (Serrat, 2017). Therefore, through the use of a systematic review and meta-analysis, this study attempts to critically examine the impacts of solar technologies at the household level between 1999 and 2019, with a focus on rural communities across the Global South and in relation to the UNDG's definition of impact and the sustainable livelihood's theoretical framework. This is to ascertain whether the research has reflected changing energy narratives during this period and if the impact indicators used, account for the multi-dimensionality of energy access. Furthermore, the potential of the consolidated information gained from this study can inform future planning and implementation of SET's in rural households in developing countries.

1.2 Motivation for the study

It is undisputed that SETs have several environmental and socio-economic benefits, and depending on the device, different energy services can be leveraged. In developing countries, such as South Africa, the roll-out of SETs and RETs have been up-scaled on the premise of improved livelihoods. However, research needs to reflect an unbiased and holistic view when investigating the impacts of technologies on households. Matosin et al. (2014) state that while the dissemination of positive research findings is straightforward, communicating negative findings was more difficult due to inherent bias. Therefore, there is a need to scrutinise impacts further to ascertain exact influences on livelihood, whether positive or negative. For example, SWHs are used extensively in rural settings, however, some studies show that long-term use is significantly hindered by limited capacity during winter months, technical failures, and the lack of maintenance (Naidoo and Munien, 2018). In addition, the use of various indicators of impacts to account for multiple impacts can be somewhat misleading. For example, a study conducted may have accounted for a decrease in energy expenditure but fail to account for an increase in water consumption and expenditure due to using more hot water provided by a SWH. In research on renewable energy, there has been a focus on the financial and technical aspects, such as their cost and functionality, with social and environmental aspects being largely neglected (Moretti et al., 2017).

Although access to energy is essential, the transition away from the MDG's towards SDG's requires innovations like SETs to promote more sustainable livelihood strategies, promote gender equality, improve household abilities to deal with and overcome stresses (climate or otherwise), improve health, and allow for improved access to education. Consequently, if research on SET impact fails to include all of the indicators mentioned above, the results could be detrimental to the future development of rural households and the solar energy technology market in the Global South. The focus on the Global South is motivated by the considerably high potential of SETs in addressing the widespread energy poverty in developing countries and their increasing investment in SETs. In addition, this study aims to determine if how the impact of solar energy technologies is investigated has changed over time by comparing the types of analyses in studies, the methods used as well as the indicators used, and the subsequent impacts recorded relative to the UNDG's (2011) definition of impact as well as the SLA framework. According to Sovacool (2019), the best chances of providing universal energy access and eliminating energy poverty depend on interdisciplinary, transdisciplinary, and socio-technical approaches that harness these diverse approaches and ways of knowing together. This is because understanding and revealing critical links between SET's and their livelihood impacts add value to the future development and implementation strategies (Nussbaumer et al., 2012). In addition, the examination of indicators used over time to assess the impacts of SETs is critical if we are to get a true and accurate reflection of the impacts caused by SETs.

Therefore, the results produced from this study systematically unpack how research on the impacts of solar technologies has changed over time. For example, a reduction in household energy expenditure could also suggest energy hybridisation, a growing phenomenon in South Africa. Munien (2016) states that many peri-urban and rural households switch between energy sources, often reverting to 'free' sources such as fuelwood, depending on the amount of income available, the type of activity, and the source's availability. In this case, specific reported impacts may have more menacing origins, for example, retrogression into deeper energy poverty. These are particularly true in cases where SETs became more burdensome to households due to technical failure (Kabir et al., 2017). Thus, in some cases reporting reduced energy expenditure may not be robust enough to garner the full extent of how these devices impacted the household. In this regard, a vital aspect of this systematic review is to examine how the impact was assessed. This type of categorisation may benefit future energy planning, especially for countries looking to extend the use of RETs and SETs for socio-economic well-being. In addition, it is hoped that the recommendations will attempt to inform how the future evaluations of SETs impacts should take place. The knowledge gained from this study may also inform the design of SET implementation strategies for households in low-income and rural communities. The study is guided by the aims and objectives described in the next section.

1.3 Research aims and objectives

Given the widespread adoption of SET's into rural households across developing countries, it is essential that the research done on the impacts these technologies have accounting for all aspects (financial, social, environmental, human, physical) in keeping with the UNDG's definition of impact and the objectives of SDG7. Therefore, the aim of this study is:

> To undertake a critical examination of how the impacts of solar technologies have been examined and measured at the household level over time with a focus on rural communities across the Global South.

An overall outcome of this study is to inform how the impact of SET's on households in low income and rural communities is researched in the future. In addition to informing implementation strategies for the sustainable introduction of solar energy technologies within rural communities in developing countries of the Global South.

The aim mentioned above will be investigated through the following objectives:

1. **To conduct a systematic review of research on the impacts of SET's on rural communities in the Global South countries.**

   According to Sofaer and Stretch (2012), systematic reviews seek to provide a comprehensive synthesis or summary of primary research on interventions or outcomes. With regards to this study, the systematic review will identify, evaluate, and summarize the literature on the impacts of SET's on rural communities in the Global South countries to establish the amount of research, the geographic scope, and the quality of the research.

2. **To critically examine how research (the types of studies, methodologies and indicators) is conducted to determine impact has changed over 20 years (1999-2019).**

   This objective seeks to systematically establish and unpack if the research conducted on the impacts of SET's has adapted over time towards changes in awareness, knowledge and understanding that energy access is multi-dimensional, and the global energy narrative has shifted its focus towards addressing energy needs as a means to ensure energy security and rural development.

3. **To establish the extent of diversity and inclusivity in the indicators used to determine the impact in relation to livelihoods.**

   Access to reliable, efficient, affordable, and safe energy sources can directly or indirectly affect an individual's livelihood in terms of productivity, income, health, gender equity, education, and many other aspects. Therefore, the extent to which the impact indicators used are diverse and inclusive compared to the SLA framework is critical for indicating whether the research being conducted can adequately account for all possible impacts of SETs on rural households.

1.4 Overview of conceptual framework

Svinicki (2010:5) explains that a framework acts as the foundation for interpreting and understanding the 'causal or correlational patterns of interconnections across events, ideas, observations, concepts, knowledge, interpretations and other components of experience'. Based on the aims and objectives of this study and since access to energy services can be an enabling asset that influences the livelihood strategies of rural households, the SLA guided this study in defining and characterising SET impacts against the capital bases it directly or indirectly affects. In this way, the study attempts to provide an alternate way to holistically capture all impacts of SET's by showing how the SLA framework's multi-dimensionality can account for the extent of diversity and inclusivity of the impact indicators and the resultant impacts recorded. Wlokas' (2010) study used an adapted version of the SLA to show that human, social, financial, physical, and natural assets were positively impacted by SETs. For example, post-installation of SWHs, households displayed health benefits alongside time and financial savings (Wlokas, 2010). In addition, improved energy security significantly decreased household vulnerability to shocks, stressors and seasonal variability (Wlokas, 2010). Therefore, the evaluation of the impacts these technologies have on rural households should combine aspects simultaneously and take into consideration all possible effects on the human, social, environmental, financial and institutional contexts. Disregarding the interdependent nature of energy with other issues would result in unsuccessful or inefficient impact assessments (Brent and Rogers, 2010).

1.5 Overview of research methodology and data sources

A mixed methodological approach was adopted for this study as it combines qualitative and quantitative data collection and analysis in a sequence of phases to satisfy the research objectives that underpin this study. The initial phase entailed a systematic review approach to acquire information about how the impacts of SETs on rural and low-income households in the Global South have been researched over time. This study utilised the Preferred Reporting Items for Systematic Review (PRISMA) 2009 and 2020 guidelines for transparent, systematic reviews and meta-analyses. Given the heterogeneity of the studies identified through the systematic review process, it was evident that a narrative analysis of the literature was needed as it is commonly used in reviews where studies cannot be directly compared (Mccabe et al., 2018).

For the systematic review, Web of Science, WorldCat and Google Scholar were used to search as it indexes the world's leading academic literature across a range of disciplines. The search was conducted using key terms and controlled vocabulary surrounding the themes "solar," "impact," "household." The search strategy across the databases was performed in three phases: database search, filtering, and analysis. The articles were filtered using exclusion criteria systematically after the initial database query, i.e., timeframe, title review, abstract review, and lastly, full-text review. Based on an established framework for the full-text review and meta-data extraction, the following information was extracted from the 56 articles selected for review: meta-information (author (s), year of publication, geographic scoping), household demographics (household size, gender, education and occupation), household energy profile (main energy need and sources of energy), nature of SET impact.

Descriptive analyses were undertaken on the percentage of literature published per category, the percentage of literature according to document type and the literature produced by the global north and south countries. Using ESRI ArcGIS software (Version 1.4), a spatial analysis was done to depict the geographic distribution based on the percentage of publications and the countries in which the studies took place. While a systematic review refers to the entire process of selecting, evaluating, and synthesizing all available evidence, contrastingly, the term meta-analysis refers to the statistical approach to combining the data derived from a systematic review (Ahn and Kang 2018). Therefore, the resultant impacts were recorded from the reviewed literature using Microsoft Excel and the Statistical Packages for Social Sciences (SPSS, IBM version 24) were then classified and statistically analysed to determine the diversity and inclusivity of indicators and the mean impacts experienced by rural households. In addition, to determine the quality and contributions made to understand the impacts of SETs on rural households, a citation analysis was conducted on the reviewed studies.

1.6 Overview of chapters

Chapter One describes the background to the study. This chapter introduces the various definitions of impact and how it could potentially impact research, especially regarding SETs. Furthermore, this chapter defines the aim and objectives that underpin the study and provides an overview of conceptual and methodological approaches used. Chapter Two details the energy provision and energy poverty narrative due to the transition from MDG's and SDGs. Chapter Two also includes literature on the development and impacts of renewable energy and SET's which is explored and compared between the developed and developing contexts. This chapter further includes literature on the conceptual framework and the use of the SLA to evaluate the impacts of energy technologies. Chapter Three offers a detailed description of the research methodologies and design of the study. Chapter Four presents the results of the systematic review and meta-analyses. Trends observed in the approaches and techniques used to determine the impacts of SET's for the 20-year cycle is also examined. Chapter Four also presents the systematic review findings in relation to the established criteria that focus on household demographics, household energy profile, and nature of SET impacts. Chapter Five, the final chapter, summarises the study's key findings and provides suggestions and recommendations for the future evaluation, development, and implementation of SET's in rural households in the Global South.

1.7 Conclusion

Access to energy has been recognised as a precondition to development, especially among low-income and rural households. Therefore, research on the impacts of SET's is critical to combating energy poverty and informing future planning and implementation strategies for these devices. This study examines published literature on the impacts of SET's on rural households in developing countries. As briefly discussed above, critical aspects such as the geographic scoping, types of studies, types of methods and the indicators used to determine impact are discussed in relation to the sustainable livelihoods approach, which will serve as an analytical framework. The chapter also defined the aims and objectives that informed this study. The next chapter will discuss the major themes, discourses and arguments that are central to understanding the multiple dimensions of SET use and the conceptual and theoretical framework guiding this study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The current study examines the impacts of SETs on rural communities in developing countries around the world. This chapter gives a brief overview of the fundamental approaches and techniques determining the impacts of SETs post-implementation. The chapter also describes the chosen conceptual and theoretical framework guiding this study. In this regard, relevant literature is examined to provide a context and motivation of how and why the sustainable livelihoods framework is used in this study to characterise SET impacts. Securing access to modern energy services and options remains a complex and multi-dimensional phenomenon requiring a more integrated approach informed by policy, socio-economic and environmental factors. Although SETs are widely promoted and increasingly included in low-income housing projects and rural development initiatives across developing countries, few studies examine the impacts of these technologies from a livelihood perspective. Therefore, the literature reviewed in this chapter provides an understanding of the multiple dimensions associated with the different types of solar technologies used at the household level. This chapter provides a critical overview of aspects considered integral in understanding the current issues within the energy dialogue by focusing on the following broad thematic areas:

- Overview of energy discourse
- Renewable energy technologies in developing context
- The role of energy access in rural development and poverty reduction
- Energy behaviours and profiles of rural households
- Research and development in the energy sector
- Conceptual framework: sustainable livelihoods approach

This chapter begins with an overview of the energy discourse, which provides the context from which many of the current energy-related challenges emanate. The chapter concludes with a review of the conceptual framework used in this study, namely, the sustainable livelihoods approach (SLA).

2.2 Literature Review

2.2.1 Overview of energy discourse

The discussion around energy on various scales, from household level to global agendas, has been influenced over time by several factors. Periodic shifts in the energy narrative may have transformed how energy is produced, consumed, and stored but what remains unchanged is the importance of energy access as an undeniable enabler of development and overall improvement of living conditions and lifestyles of individuals (Pachauri et al., 2012; Franco et., 2017). Examining historical and present trends in the energy discourse gives insight and a reference point to the eventual introduction of renewable energy, specifically solar technologies, which is central to the current study.

The Industrial Revolution initiated human-generated electricity, and the world made the transition from wood to coal then to oil and gas (Caineng et al., 2016). During this time, it became increasingly apparent that energy contributes to fulfilling the most basic human needs, including nutrition, warmth, and light. Furthermore, there was a significant amount of evidence that revealed that access to reliable, efficient, affordable, and safe sources of energy can affect productivity, income, and health and can improve gender equity, education, and access to other infrastructure services (Pachauri et al., 2012; Raspaud, 2012; Pueyo and Maestre, 2019). However, the global demand for fossil fuel-based energy increased exponentially with increasing population sizes and industrial expansion, highlighting significant issues with energy use and the subsequent negative impacts on people and the environment (Jebaselvi and Parmasivam, 2013).

The increased demand rapidly depleted the finite reserves of these non-renewable sources of energy, which resulted in exponential price increases (Gori, 2014). While many countries worldwide benefited from the energy transformation, the excessive use of fossil fuels and the subsequent release of greenhouse gasses (GHG) was linked to the significant increase in environmental degradation and air pollution (Majeed and Mazhar, 2019). According to the World Resources Institute (2017), from 1990 to 2017, their records have reflected that the primary sources of GHG emissions are electricity and heat. The most recent projection shows that 31% of GHG stems from electricity production, 11% from agriculture, 12%-15% from transportation and manufacturing (World Resources Institute, 2017). Furthermore, the looming energy crisis garnered great concern and highlighted that energy resources are unevenly distributed worldwide, creating imbalances in the accessibility, development, and production of energy between countries (Dugoua and Urpelainen, 2014). Most apparent are the patterns of energy consumption that are unevenly spread across the development gap – North and South, affluent and poor, men and women, rural and urban (Pachauri et al., 2012). This inequity in energy access and consumption compromise the well-being of individuals and deprives them of progressive opportunities and the ability to engage in modern lifestyle practices (Sovacool et al., 2012).

Between 2000 and 2015, the MDG's had been adopted by 191 countries at the United Nations General Assembly, thereby dominating the global agenda by prioritising the eradication of extreme hunger and poverty and the provision of basic needs like access to water and sanitation and improving healthcare, especially for women and children (Abubaker and Aina, 2017). Most of the goals and targets were set to be achieved by 2015 based on the global situation during the 1990s. Even though none of the eight MDG's explicitly addressed energy, it was found that access to sustainable and clean energy indirectly contributes to achieving some of the MDG's (Oluoko-Odingo and Mutisya, 2018). Figure 2.1 shows that in 1990 more than 1.5 billion people had no access to electricity; this had fallen to below 1 billion by 2015 (Ritchie and Roser, 2019). This suggests significant progress in a short amount of time. Overlapping this trajectory is the third major transformation in the energy sector, specifically the shift from oil and gas to renewables (Ritchie and Roser, 2019).

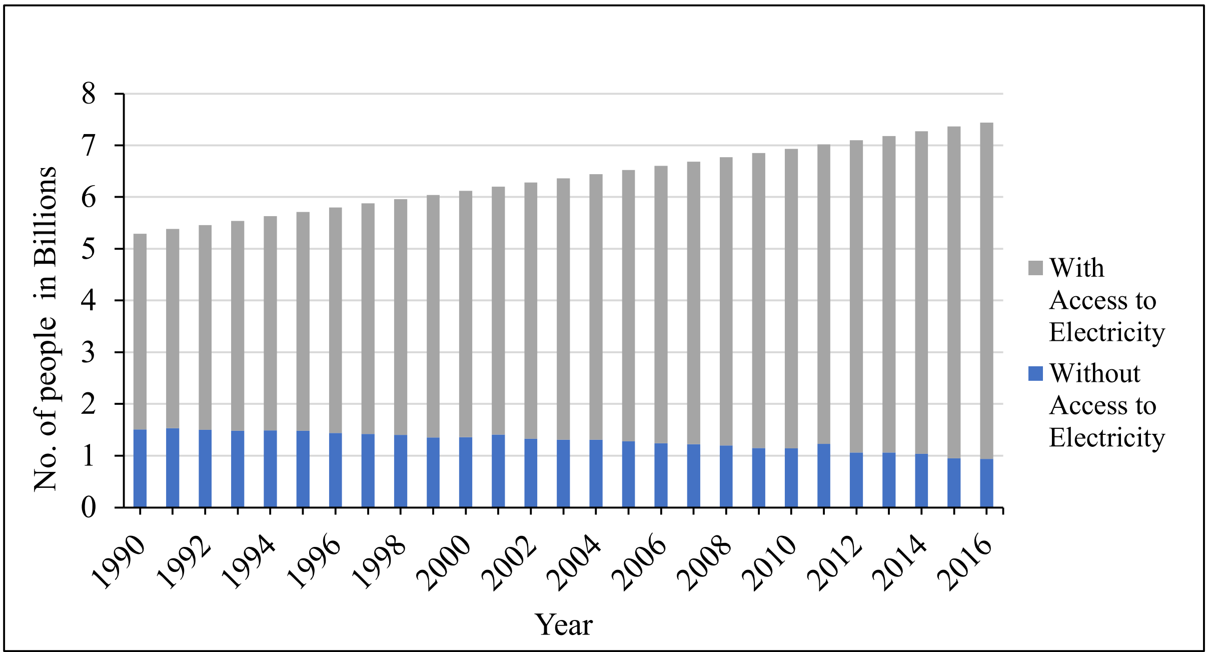

Figure 2.1: Global access to electricity (Adapted from Ritchie and Roser, 2019)

Although renewable energy use predates the UN’s 2002 World Summit on Sustainable Development, this conference was the first of many to add to its agenda the importance of access to basic, clean and energy in supporting the development and poverty eradication (Baluch et al., 2015). However, it was the Renewables 2004 Conference in Bonn, Germany and the 2005 Beijing International Renewable energy conference that set the foundation for an expansion of renewable energy around the world and enforced the understanding that renewables can contend with traditional energy sources and provide a basis for global development going forward (Baluch et al., 2015; Arutyunov and Lisichkin, 2017; Renewables, 2019).

Renewable energy provides an alternative to fossil fuels that are being utilised faster than replenishment rates and have dire consequences for GHG emissions and environmental well-being (UNCTAD,2010). Jebaselvi and Parmasivam (2013) suggested that the best way to transform the current reliance on fossil fuels is to shift to renewable energy sources as it provides an alternate source for meeting basic energy needs. Furthermore, the shift to renewable energy is also associated with reducing pollution, carbon emissions and achieving sustainable socio-economic and environmental development goals while meeting individuals' demands or need for energy. Gielen et al. (2019) assert that two-thirds of the total global energy demand can be supplied by renewable energy, in addition to reducing GHG emissions by 2050 to keep global warming below 2°C. Furthermore, Vetter (2021) reported that the costs of these renewables are decreasing rapidly enough that fossil fuels could be phased out of electricity generation entirely by 2035.

However, according to Gratzel (2005), the reality of acquiring benefits from renewable energy sources (e.g., wind, solar and hydro) requires it to be adopted on all scales from local to global and warns of threats to the quality of life if renewable energy sources were not embraced fast enough at all levels. While most renewable energy projects are presently carried out on a large scale, RET’s are also suitable for small off-grid applications, especially in rural and remote areas, where energy is often critical for human development. One such renewable source of energy is solar energy, which is considered a clean, powerful, and safe energy source that serves as an excellent alternative to alleviate the environmental problem and address energy security (Ellabben, 2011).

Solar energy generally refers to the energy that has been harnessed from solar radiation (Baluch et al., 2015). Solar energy can be utilised in many ways, including generating electricity through photovoltaic (PV) solar cells, systems that concentrate solar power by heating trapped air, generating hydrogen using photoelectrochemical cells, and heating water or air (Kabir et al., 2018). Solar energy technologies like solar geysers, heaters, refrigerators, air-conditioners, solar thermal cookers, pumps, and battery chargers can be used instead of their coal generated-electricity equivalents (Kabir et al., 2018). In recognition of the benefits of renewable energy, countries worldwide began introducing policies to encourage their development and implementation into various sectors, which would have the most significant impacts (Baluch et al., 2015).

However, IEA (2017) revealed that despite an increase in the renewable energy sector, the reliance on coal and oil remained high, thus adding to mounting concerns that the rate at which these resources are consumed for electricity production is causing extensive environmental damage (Munien, 2016). These concerns were in addition to the need to provide energy service to the 952 million people that did not have access to electricity globally (Ritchie and Roser, 2019). Therefore, to build on the progress made by the MDGs and complete what had not been achieved, the SDGs were introduced at the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012 (Baluch et al., 2015). The succession to the SDG's was a universal attempt to "transform our world" to become more sustainable and resilient (Abubakar and Aina, 2017:2). The objective was to generate goals that urgently address the environmental, political and economic challenges facing our world by 2030. Essentially the establishment of the SDGs acted as an urgent call to shift the world onto a more sustainable path, especially regarding energy provision, which emerged as its SDG and critical topic for discussion on the global agendas going forward (Raspaud, 2012).

Sustainable energy provision was highlighted by SDG7, which drew attention to the importance of energy for sustainable development by calling for action to ensure access to clean, affordable, and reliable energy for all (McCollum et al., 2018). In addition to access to energy being recognized as a critical enabler for development, a higher share of renewable energy and extensive improvements in energy efficiency became a significant part of global priorities for sustainable development (Gielen et al., 2019). Therefore, moving forward, the global community recognised that access to affordable, reliable and sustainable sources of energy supports economic and social development, without which poverty eradication would be near improbable (Pachauri et al., 2012).

The setting of new targets coincides with the transition to the SDG's, incited governments to renew their commitments towards achieving them. The narrative changed from providing energy access to looking at energy poverty in its entirety and addressing the energy needs of households to ensure that the difference made will be sustainable. This direction towards understanding energy poverty offers vital opportunities to develop strategies for providing energy services that are ecologically sustainable and associated with improving the quality of life (Samarakoon, 2019). However, the multi-dimensionality of the world's energy needs meant no single simple and straightforward solution. In this regard, RET's have been widely marketed to offer some potential solutions. Furthermore, the gap between expectations of rapid, renewable-driven energy changes and the extensive reliance on fossil-fuel-based energy systems poses several challenges (World Energy Outlook, 2019).

2.2.2 Solar energy technologies in the developing context

Solar energy is accepted worldwide as the largest source of renewable energy supply (Chakraborty et al., 2016). Most developing countries offer a unique opportunity to expand the solar industry as most are located in remote regions with optimal access to the sun's energy (Figure 2.2). According to Chang et al. (2011), most countries considered to be developing lie in the zone known as the 'sunbelt,' located within 35 degrees of the equator, exposing them to abundant amounts of solar radiation throughout the year. The World Bank (2020) the Middle East, North Africa, Sub-Saharan Africa regions, Afghanistan, Chile, Iran, Mexico, Pakistan, and Peru have significant solar PV potential. This is attributed to these countries having access to a constant solar energy supply between seasons (World Bank, 2020). According to Adenle (2020), African countries have tremendous potential for installing solar technologies. Despite the abundance of this resource, it is concerning to note that almost 1 billion people are still without basic energy services, of which more than 570 million live in sub-Saharan Africa and in developing Asia (Falchetta et al., 2020).

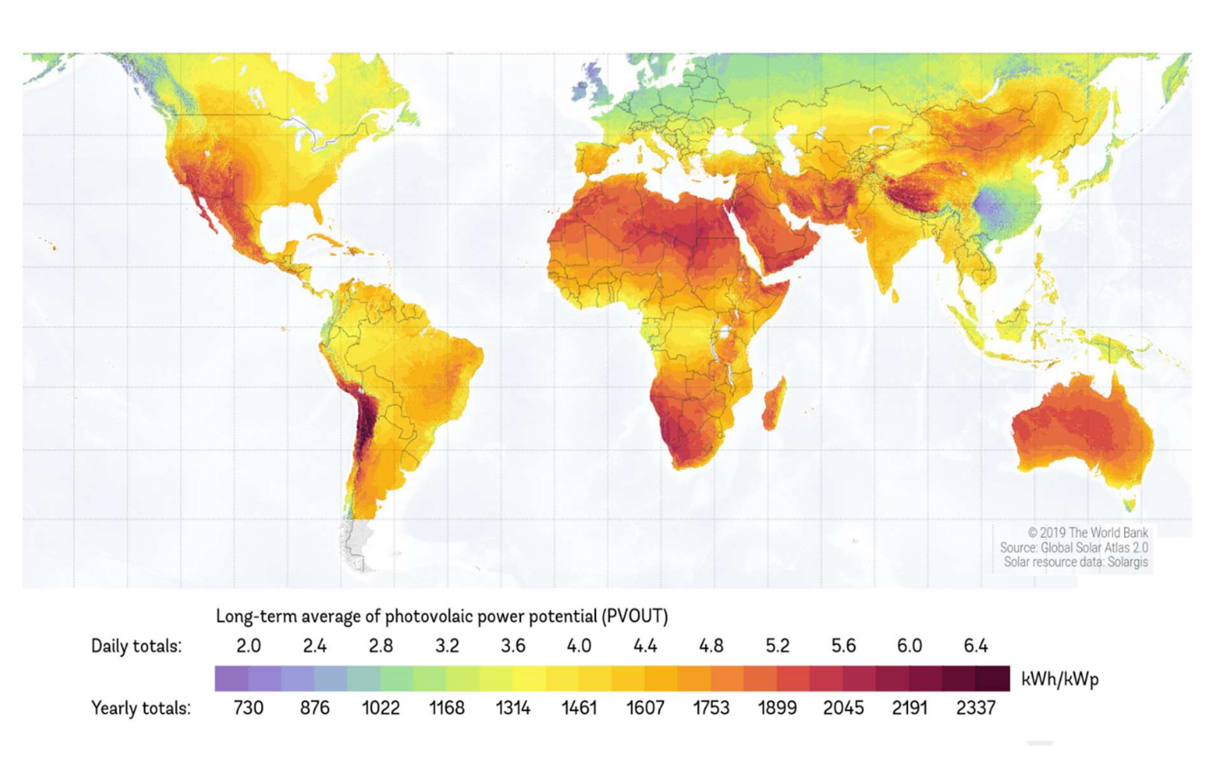

Figure 2.2: Global solar irradiation levels (Source: The World Bank, 2019:1)

Ellabban (2014) attributes the expansion of the global energy market to the competitiveness of solar PV systems in addition to the increasing demand for electricity in developing countries coupled with the rising awareness of potential these technologies have in combating pollution, decrease carbon dioxide emissions and the ability to provide better access to energy (Ellabban, 2014). For several consecutive years, the investment into solar power has grown alongside installation capacity (Figure 2.3). In 2016, solar PV was the second-most positioned renewable technology and accounted for 43.3%of the newly installed renewable power capacity, followed by wind and hydropower at 32.7% and 17.7%, respectively (Kalliappan et al., 2019). According to the Global Status Report (2020), solar PV generation increased by 22% in 2019 and had the second-largest growth behind wind and ahead of hydropower. Despite slowing growth due to recent policy changes and uncertainties in China, 2019 was a year of record global growth in solar capacity. According to Chowdhury (2019), the two developed countries leading the global generation of solar power are Germany and Japan, while the two developing countries are China and India. In 2015 and 2016, the installation was higher than the past 24 years, where the largest ever solar power projects capacity of 20904MW was tendered, and 31472 solar pumps were installed (Kalliappan et al., 2019).

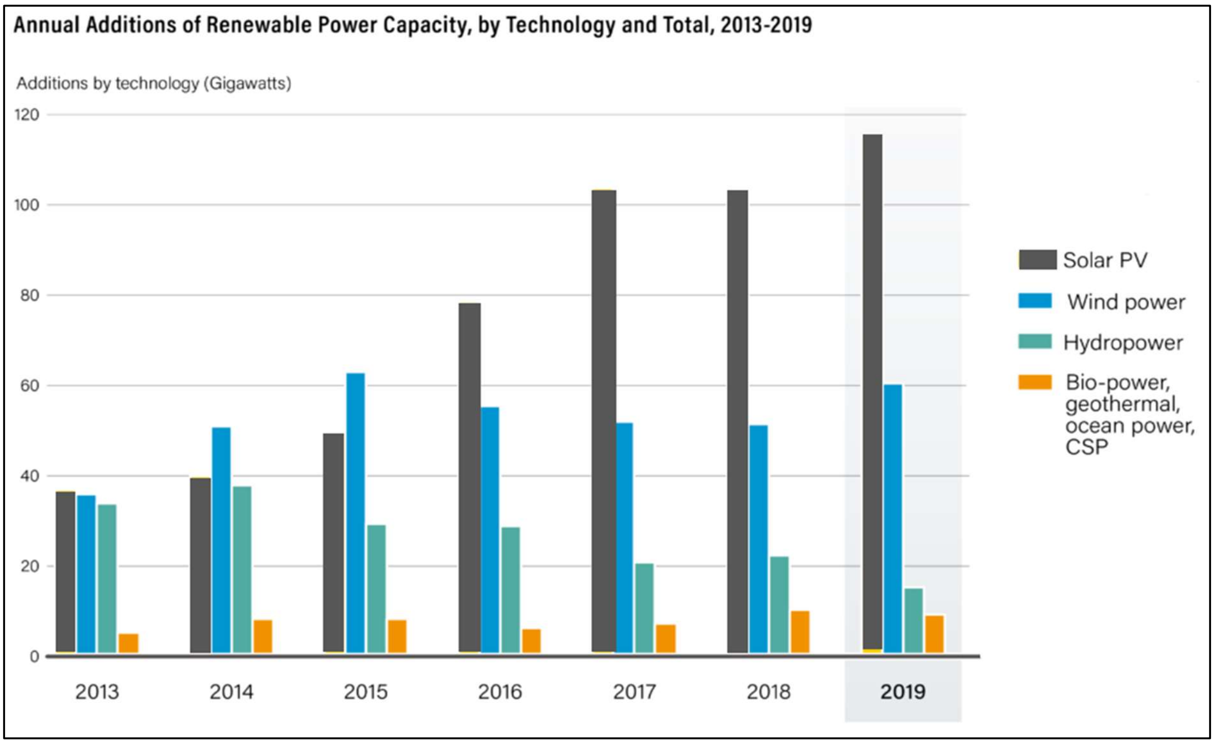

Figure 2.3: Annual growth in renewable energy capacity (Source: Global Status Report, 2020 :46)

With the development of solar markets and the emergence of new renewable energy targets set to take advantage of the solar economy, solar power's accessibility and affordability are expected to increase further (Gielen et al., 2019). Sub-Saharan Africa, East Africa, and to a lesser extent in South Asia and Latin saw the sale of SETs such as PV-based solar lanterns, solar chargers and solar homes reach 130 million units between 2010 and 2017, and it is expected to increase to up to 250 million units in 2017–2022 (Hansen et al., 2020). India has established the most extensive clean energy programme in the world, initially set out to achieve 100GW of solar power by 2022 and is now on the way to achieving its extended renewable energy goal of 450 GW by 2030, which means a higher expected installed solar capacity (Deshwal et al., 2021). Amongst developing countries, the SETs rolled out at the domestic level include SWH, SHS, solar PV systems, solar lanterns and solar cookers (Bensch et al., 2015; Mishra and Behra, 2016; Chen et al., 2017; Aydin et al., 2018; Mendoza et al., 2019).

However, these factors for expansion are dependent on suitable financing tools, ongoing subsidies to fossil fuels in many countries, social and political unrest in some, a reliance on tenders for new capacity, and a race to the bottom in bid prices (Global Status Report, 2021). However, at present, there are several limitations as well as benefits associated with the use of

SETs (Kabir et al., 2018). The high cost of installation is a significant drawback of the SET's as well as long payback periods and small income streams also reduce the value of the benefits received for such systems (Palm, 2018). Similarly, Chang et al. (2011) attribute the hesitation in the large-scale implementation of SET's like solar geysers and solar PV systems to costs as more traditional forms of heating such as liquified petroleum gas (LPG) and natural gas or coal-generated electricity may be cheaper. Although solar power systems require an initial investment for installation, they generally operate at very low costs (Dobrotkova et al., 2018; Hossain et al.,2019). Unlike fossil fuels, which are prone to substantial price swings, the financial demand for solar power is relatively stable over long periods (Kabir et al., 2018). The performance limitations of other components such as batteries and inverters are parts of the SET that require improvement (Hossain et al., 2019). For instance, batteries have a short lifetime and are often large and heavy, needing adequate space to accommodate their dimensions. Another shortcoming is that solar energy is unreliable in regions with unsustainable weather or climate conditions or when air pollution levels at the installation site influence the solar cell's effectiveness (Kim et al., 2017). Therefore, owing to these limitations in terms of the system design and assimilation, the operating expenses of the entire system are significantly increased (Chakraborty et al., 2016).

Ellabban (2014) attributes the expansion of the global energy market to the competitiveness of solar PV systems in addition to the increasing demand for electricity in developing countries coupled with the rising awareness of potential these technologies have in combating pollution, decrease carbon dioxide emissions and the ability to provide better access to energy (Ellabban, 2014). However, these factors for expansion are dependent on suitable financing tools, ongoing subsidies to fossil fuels in many countries, social and political unrest in some, a reliance on tenders for new capacity, and a race to the bottom in bid prices (Global Status Report, 2021). Nonetheless, the efficiency of solar power technologies has increased significantly over time and has been characterised by a progressively steady decline in costs, which are projected to drop even further (Kabir et al., 2018). The IRENA Report (2018) has envisioned that solar power will account for 11% of the global electricity generation by 2050 and solar electricity contribution around 20% of the global energy supply (Kalliappan et al., 2019).

In contrast, the Global Status report (2019) explains that despite significant strides made in the adoption of renewables, the world is not on track to meet the targets of the Paris Agreement or SDG 7. The UNFCCC (2021) and Vaisanen (2020) shared similar sentiments when explaining that the national targets, plans and strategies implemented by nations need to be more ambitious, there is a need to promote the uptake of renewables through incentives and subsidy schemes and improve the efficiency of modern energy technologies. Therefore, to achieve steady and sustainable growth in renewable energy use, governments should design and implement effective support policies to promote investment, incentives, and the adoption of new technologies like SETs (Shafiei and Salim, 2014).

2.2.3 The role of energy access in poverty reduction and rural development

According to the United Nations Conference on Trade and Development (UNCTAD) (2010), the role of energy is to facilitate the reduction of poverty through rural development. Although energy services alone will not eradicate poverty, access to energy is an enabling factor of economic development, education, health, social inclusion, and environmental protection (Colombo et al., 2018; Xu et al., 2019). On a global scale, poverty reduction and the use of clean energy with the subsequent lowering of carbon emissions were two of the SDG goals agreed upon by 193 countries worldwide (Abubakar and Aina, 2019). Compared to the more developed countries that signed the agreement, the Global South countries have to address the complex dual challenge of meeting the needs of people who lack access to energy services while joining in on the global transition to sustainable low-carbon energy systems (Pachauri et al., 2012). Presently, over one billion people across the globe still lack access to essential energy services, 97% of which live in the Global South countries like in sub-Saharan Africa and Southeast Asia (Yadav et al., 2019). Furthermore, 85% of the world's unelectrified households are in rural and low-income communities (The Energy Progress Report, 2020). These communities face geographic isolation, low unemployment rates, lack of income, infrastructure and resources, and environmental degradation (Chen et al., 2017).

The use of unprocessed solid fuels as a source of energy is primarily found in rural areas of developing countries, particularly among low-income households (Ravindra et al., 2019). Approximately 2.7 billion people use wood or dung as their primary source of cooking and heating fuel, and lack access to modern energy services, thus rendering them energy poor (Islam et al., 2017). Likewise, many rural communities in Nepal spend more than one-third of their household income on energy services (Sapkota et al., 2014). These households depend heavily on biomass and fossil-fuel-based energy in firewood, charcoal, and kerosene to meet their basic energy needs (cooking, lighting, and heating). A further consequence is the negative health impacts associated with using these traditional sources of energy (Pachauri et al., 2012).

The UNDP (2011) and World Health Organisation (WHO, 2009) reported that respiratory infections due to indoor and extended use of traditional energy sources account for over a million deaths a year, with a significantly higher percentage of women and children in the Global South.

Additionally, household members have to devote a large portion of their time to energy-related activities, more commonly with women and young girls spending more than 6 hours a day gathering wood, collecting water, and processing agricultural products (Sapkota et al., 2014). Figure 2.4 illustrates the main dimensions of improved access to sustainable, cost-effective, safe and modern energy sources, underpinning its importance in facilitating socio-economic and environmental well-being (Gielen, 2019). For example, the loss of productive daylight hours due to energy acquisition and/or use is an obstacle for many, particularly women and children, to engage in activities that could improve education, income generation and social support (Lemaire, 2018; Yadav, 2019). Clearly, the impacts of energy poverty are experienced disproportionately among the energy-poor, and SETs can provide some relief across these cross-cutting impacts of energy poverty (Munien and Ahmed, 2012).

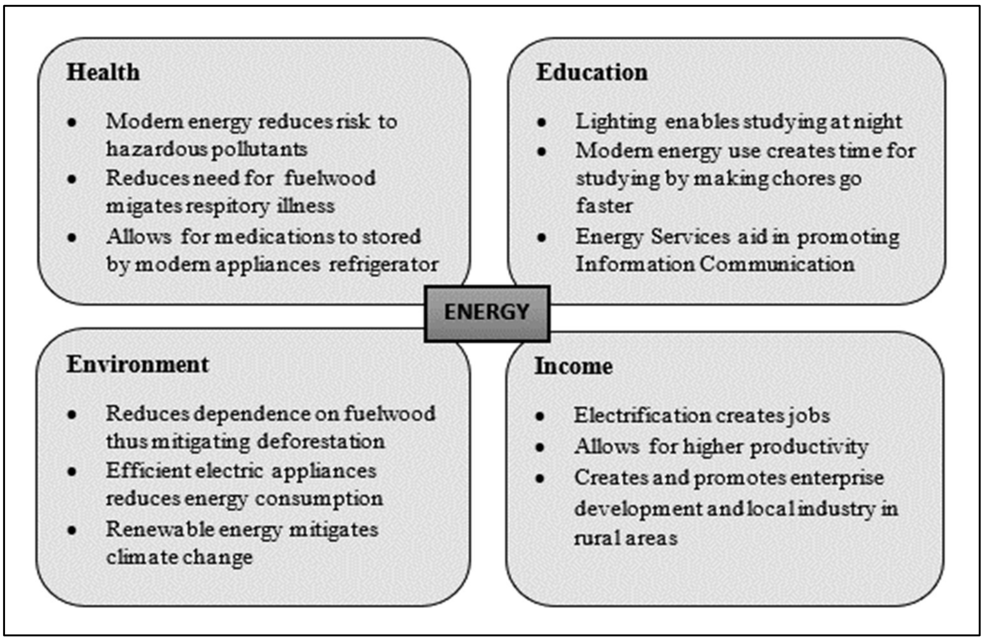

Figure 2.4: Dimensions of improved energy access (Adapted from Kanagawa and Nakata, 2007)

A prediction made in 2003 estimated that the number of individuals utilizing fuelwood will increase by approximately 40% to about 700 million people in Africa by 2030 as the price for fossil-based sources of energy increases and becomes unaffordable by the people (EIA, 2008). This can be attributed to the two-way relationship between inexpensive energy services and poverty. For example, individuals lacking access to cleaner and affordable energy are repeatedly confined to a cycle of deprivation, low incomes, and limited opportunity to improve their living conditions while simultaneous using substantial amounts of their low income on cheaper and unhealthy forms of energy (Karekezi et al., 2012). This scenario signifies danger for livelihood sustainability of rural households and their need for an off-grid solution that can be used by rural and low-income households (Torero, 2015). Rural electrification and grid extension to remote and sparsely populated communities can result in higher energy costs for these households compared to urban households. Merely extending energy infrastructure is economically inefficient for both public and private providers, underscoring the importance of energy access and suitable, sustainable and cost-effective energy sources.

According to the International Energy Agency (2017), off-grid renewable electricity, especially solar, provides the most viable way to ensure that all individuals have access to electricity in rural areas. As mentioned, RET's provide a bottom-up and demand-led approach that can complement a top-down planning approach based on the grid (Scott and Worrall., 2018). For rural and low-income households, renewable energy sources (wind and solar energy) can deliver cheaper and cleaner power than grid extensions. The expansion of renewables in rural areas facilitates development by creating jobs and enables other social benefits, such as access to information technology (OECD, 2012). Developing countries are making significant progress given the vast potential of renewable resources available in countries of the South (Chakraborty et al., 2016).

A study by Kibbria (2015) reveals that households developed new income sources and/or enhanced their current sources, secured long-term job opportunities, and established several community-based initiatives that gave rise to skills and capacity building post-installation of select RETs. Kibbria (2015) concludes that generating reliable and cheap energy can stimulate economic development, alleviate rural poverty, improve the quality of life of rural men, women, and children, decrease air pollution, generate local employment opportunities and enhance food production. Sharma et al. (2019) show that children using solar lights increased the number of hours studying a day resulting in enhanced academic performance. Other studies found that the only positive impact of solar lanterns/lights was improved child health attributed to reduced use of kerosene (Furukawa 2014;Nandasena, 2013). In addition, Aydin et al. (2018)

report that SWH helped reduce environmental impacts from energy use, as it provides an alternative for solid fuels in many developing countries, but their performance and impacts depend on the weather and climatic conditions. Adenele (2020) reported that in Western Kenya, subsistence farmers have benefited from solar-powered irrigation pumps and solar PV systems through agricultural extension services and products to deal with drought and unreliable rainfall, thus improving the probability of a successful yield and maintaining food security.

From above, it is evident that it is extensively known that access to energy is of paramount importance in most developing economies, however, the success of these RETs in households is influenced by concerns of cost, technical know-how, ownership, and long-term maintenance (Munien, 2016). As mentioned, the high upfront cost of SETs deters adoption at the household level (Prasad et al., 2020). Technical know-how refers to the household members' knowledge and ability to operate and maintain the system if the installation company provides no after-sale services. Therefore, there is a need to understand the forces affecting households in their choice of particular energy before understanding shifts in fuel use (Uhunamure et al., 2017)

2.2.4 Energy behaviours and profiles of rural households

The Energy Cultures framework (2014) explains that energy behaviour refers to all human activities influencing how fuels (electricity, gas, petroleum, coal) attain certain products and services. To this effect, the development and implementation of SET's into rural households must be guided by their energy behaviours and energy profiles to ensure the sustainable use of these technologies. In developing countries, rural households' energy behaviours and profiles tend to be limited by their socio-economic conditions (Bisaga and Parikh, 2018). For example, the households in the rural village of Chhattisgarh, the fourth poorest state in India, could only afford kerosene and fuelwood for cooking, heating and lighting purposes (Millinger et al., 2012).

There is no immediate prospect of connecting to the central electricity grid for many rural communities, and other commercial energy sources are often too expensive. Sovacool (2012) notes that access to energy in low-income communities suffers limited financial incentives for energy companies, thus discouraging further energy infrastructure investment. Other barriers such as political and institutional inefficiencies concerning ineptitudes in implementation, corruption, theft, vandalism, and a lack of knowledge may also contribute to social unrest and protests (Sovacool, 2012). As a result, rural households rely primarily on solid fuels from biomass, such as firewood, charcoal, farming waste, and animal dung, to meet their cooking energy needs (Ravindra et al., 2019). Biomass fuels are typically used for cooking, space heating, heating water for bathing, and meeting some industrial heating needs (Gautam et al., 2019). Although much of the world's rural population have no access to electricity generation, many have small battery-operated devices such as radios and flashlights (Goldemberg et al., 2000). In many countries, these resources account for over 90% of household energy consumption, but despite this, the likelihood of transitioning to other more modern energy sources is slim (Mishra, 2016).

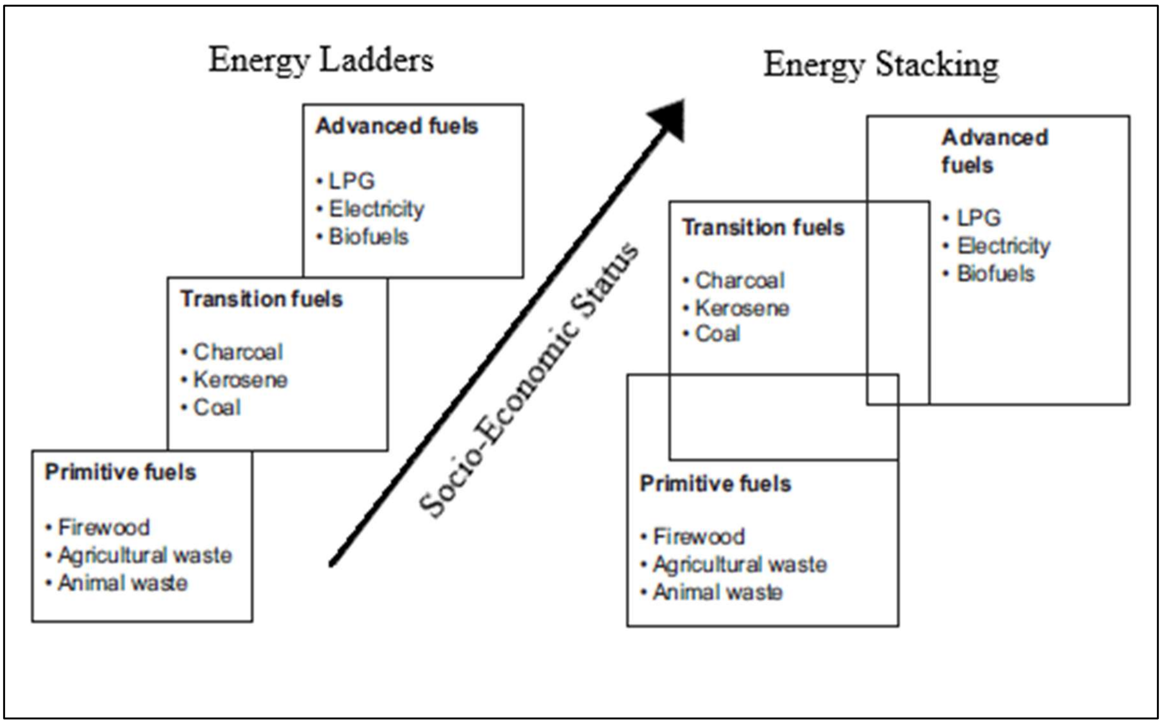

Figure 2.5: Energy transitions based on the energy ladder and energy stack model (Sourced from: van der Kroon et al., 2013:505)

In order to understand these energy choices, several theories were put forth, with the energy ladders and energy stacking hypothesis being the most recognised (Bisaga and Parikh, 2018). The 'energy ladder' is a well-established model that resource economists have employed to illustrate how households advance to more 'sophisticated' domestic fuels as economic conditions improve (Maconachie et al., 2009). The energy ladders hypothesis explains that households will discontinue traditional sources of energy and subsequently start using modern sources of energy like solar energy only when there is an increase in their socio-economic status (Figure 2.5) (Van der Kroon et al., 2013). Behera et al. (2017) explain that electricity is at the top of the energy ladder of household energy use that depends primarily on household members' wealth status, income, and education levels. Movement up the energy ladder can occur within various aspects of rural life: agriculture, household cooking, household lighting, heating (UNCTAD, 2010). The primary assumption of the theory is that rural households will move up the energy ladder and will substitute biomass fuels (such as wood or crop waste) with kerosene, LPG, or electricity as their income increases. Similarly, households can retrogress as affordability and availability of funds decrease (Bisaga and Parikh, 2018).

The energy ladder has been widely criticised for representing the energy transitions as linear movements (Mensah and Adu, 2015). Munien (2016) explains that models such as the energy ladder fails to map features such as energy hybridisation (a common practice in South Africa) and socio-cultural practices. An alternate view of the household energy transitions lies within the energy stacking hypothesis, which states that as the household's income increases, it will move towards the simultaneous use of different types of fuels, i.e., the use of more than one type of fuel (Masera et al., 2000). According to Choumert et al. (2017), this energy stacking refers to how low-income households typically use various traditional fuels such as firewood, animal residue, and charcoal. However, as that household's income increases, they assume the use of modern fuels and continue using traditional fuels for some activities, thus 'mixing' different energy sources. According to Uhunamure (2017), it is common to identify how households mix energy sources for different activities; for example, a household may use fuelwood for spatial heating and gas for cooking, consequently mixing modern and biomass energy sources.

Jan et al. (2011) show that even in cases where rural households have access to various sources of energy, reliance on biomass fuel for domestic use remains persistent. The study concluded that income is not the only determinant of transition from traditional to more convenient forms of energy; other factors such as alternative energy sources and consumer preferences explain household energy behaviours and profiles. According to Barnes et al. (2011), the demand for energy by households is influenced by household-level factors such as the highest level of education attained, preferences and the ability to afford certain types of energy, and community-level factors such as energy price, infrastructure, wage structure, and commodity prices. Munien (2016) provides another explanation for rural energy behaviours and profiles, stating that adopting modern sources of energy in place of traditional sources is linked to the recognition of enhanced energy services and benefits to the household members. Kaygusuz (2011) explained that utilizing modern forms of energy is linked with increased productivity at a household level, and the resultant impacts become evident within the first hour of using electric power. For example, electricity provided enhanced services such as lighting and increased total productive hours per day, which initiated the shift to electric power from traditional biomass (Munien, 2016).

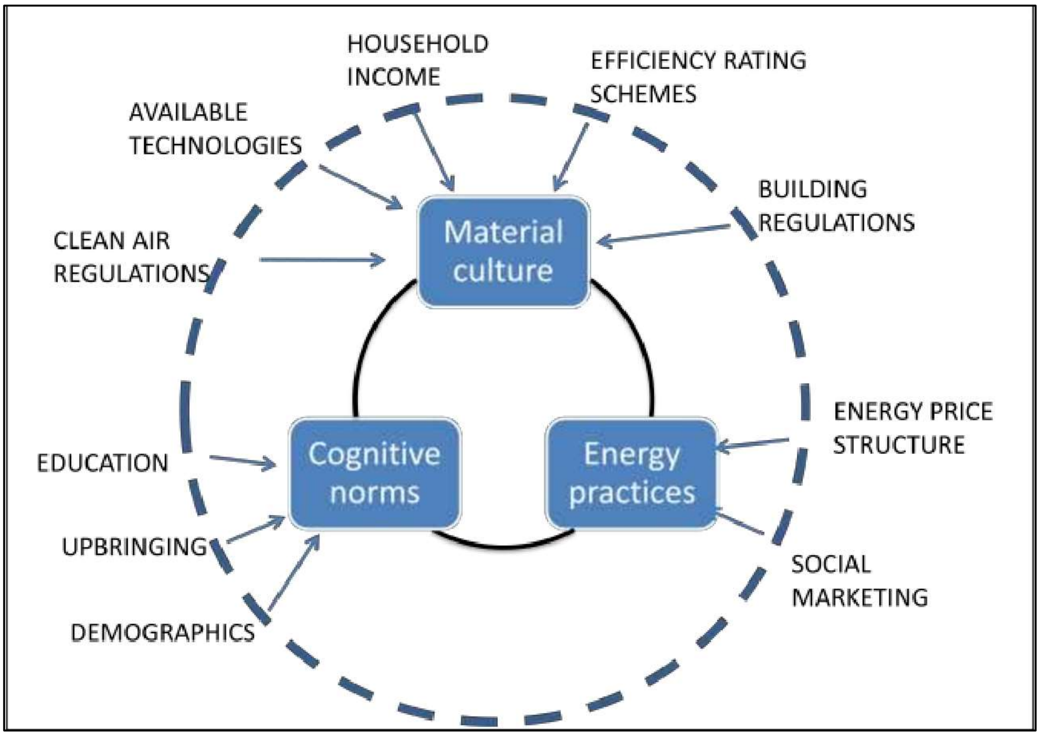

Figure 2.6: The Energy Cultures Framework (Source: Stephenson et al., 2010: 6124)

Stephenson et al. (2015) developed the framework (Figure 2.6) to understand better household energy behaviour and of opportunities to support the adoption of more energy-efficient practices and technologies. In addition, the framework attempts to understand why individuals maintain certain behaviours regarding what energy source they use and how they use it (Stephenson et al., 2010). The framework argues for the need to view energy behaviour as a product of the interrelatedness between norms, practices, and material culture and their mutual causality (Figure 2.7). Furthermore, the framework acknowledges the relationships between external effects and any elements of an energy culture that may have a part in forming, strengthening, or destabilising that culture (Jürisoo et al., 2019). This offers a more robust framework to examine energy behaviour and is essential when considering the impacts of specific SETs. For example, the manner in which SETs are used could be an outcome of the above influences. Thus, no matter the intended benefits of SETs, households may only leverage those compatible with their choices.

The model examines a host of influencing factors, including material cultures, household income, social influences, satisfaction with current energy technology, the individual's knowledge and awareness of the environmental impacts of current energy technology, and the value of utilizing SET's (Jürisoo et al., 2019). According to Stephenson et al. (2015), the cognitive norms refer to the individual and shared expectations and aspirations about 'everyday behaviour' regarding a type of energy source to use. Energy practices are used to refer to the usual or customary actions used by households with regards to their energy use which consists of the interaction between their material culture, cognitive norms, and energy practices, which is shaped by external influences such as level of and access to education, income, available technologies and social marketing amongst others (Ford et al., 2017).

In addition, external forces influence behaviour patterns, create resistance to change, drive the adoption of new behaviours and vary according to the energy culture under inquiry. Therefore, based on the framework to change the energy behaviours of rural households requires a change in more than one part of the framework, this is because energy-related practices and decisions provide the context of the entire framework (Ford, 2012). In this regard, the entire energy culture of an individual or household is required to shift if it is to adopt a new energy practice or technology. Understanding the energy cultures of rural households will aid in producing implementation strategies that are directly suited to the wants and needs of rural residents concerning the adoption of SETs (Stephenson et al., 2010). Behaviour as a factor that influences the impact of RET's and SET has rarely been discussed in households. However, Timmins (2018) asserts that investigating behavioural aspects such as energy consumption will allow for interventions aimed at sustainable energy to be more successful if they target important past energy behaviours, thus removing a significant barrier to change. Based on the above, there is a clear indication that programs and technologies aimed at increasing access to energy in rural community's need to be informed by local energy needs, resources, and existing institutional arrangements and capabilities if they are going to succeed in their efforts to implement and develop modern sources of energy.

2.2.5 Impact research in energy studies

Research and development are considered two separate entities, but development would cease and fail to be successful without research. In the case of this study, insight into research and how it influences development on a larger scale has far-reaching implications that will aid in understanding the results obtained through the systematic review approach used in this study. In academia, research is used as a process to identify solutions to problems or explanations of phenomena experienced at various levels of society. Namanji and Ssekyewa (2012) explain that for research to take place, there needs to be the presence of a problem or question that becomes the catalyst for establishing solutions and potential answers.

Impact research studies aid in diverting the focus away from the research process and towards the overall purpose and value of research (Morton, 2015). Impact studies are important to several sectors such as business, education, and government because they seek to measure improvement levels within various sectors. These studies are primarily done to measure the effectiveness of new initiatives or policies on a group of people and are vital to the development within these sectors because as it determines change (Garbarino and Holland, 2009). Lastly, impact studies contribute to continuous learning in various sectors to distinguish adverse outcomes or effects. By studying past shortfalls, the relevant people can improve their ventures to ensure the best possible impacts occur (Political Analysis SA, 2018). Regarding this study, impact research undertaken to assess the main effects of energy technologies at the local level becomes necessary to highlight successful strategies (Colombo et al., 2018).

The apparent drawback of impact research is that the impact mechanisms are subjective and will likely be diverse; therefore, how impact occurs and how it is identified will not be appropriate in all circumstances (OECD, 2014). In addition, the variation in the way research is undertaken, communicated, and evaluated has created barriers between the results and those who may benefit from it. This may be due to 'impact' being a multi-dimensional concept that can be defined in several ways. There are two definitions of the word 'impact' given by the Oxford English Dictionary: 'the action of one object coming forcibly into contact with another' and 'a marked effect or influence' (Hearn, 2016). These are two extensively used definitions, each of which contains different views of causality and, as a result, will have a significant influence on development processes and how programmes are designed, managed and evaluated (Hearn and Buffardi, 2016). Similarly, there is a difference in the definition of impact given in statistics and econometrics, which describes impact as a measure of difference from a pre-defined indicator.

In broader terms, the OECD-DAC definition describes impact in relation to long-term effects, whether the effect was intended or unintended, whether it is a negative or positive effect, and lastly, whether it was an indirect or direct effect. In addition to these varying definitions of impact, there is a common classification of two different types of impact in the literature, i.e., instrumental and conceptual impact. Instrumental impacts can be described as direct influences on individuals, policymakers, and other practitioners' behaviours and decisions. In contrast, conceptual impacts refer to knowledge, attitudes, perceptions, and understanding (Nutley et al., 2007).

According to Wallman-Stokes et al. (2013), the impact is subjective; it is defined by a person or group and for a person or group. Impact definitions are not abstract, objective truths, and this confusion around how to define and classify impact have perpetuated some common misconceptions and biases being present in research. The first misconception lies in that impact is always a 'positive change.' Taking for granted that impact is always a positive change will undervalue and undermine research contributions and the many effective organizations working on complex problems or under challenging conditions. The other misconceptions are that some impacts are immeasurable and must be attributed to something or someone. However, while some impacts like a change in attitude are difficult to relate to one singular cause, they can still be measured. Another misconception is that impact cannot be an outcome of one's actions. Wallman-Stokes et al. (2013) provide an example that if the average income of women were raised, few would attribute it to the outcome of their actions e.g., using modern energy, while most would see it in terms of a larger consequence of an overall improvement women's status in that community. However, Wallman-Stokes et al. (2013) state that there is no single correct answer, and it is necessary to define impact at the beginning of any study.

According to Namanji and Ssekyewa (2012), in order for development to occur, research needs to be done holistically. In the case of impact research, with all of the above considerations, it is integral that the chosen definition of 'impact' is inclusive (Wallman-Stokes, 2013). This is because impacts by any definition are likely to be diverse, and one generic notion of and about how impact occurs will not tailor to all circumstances (OECD, 2014). This was reiterated by Hearn and Buffardi (2016), who note that no single definition will be universally accepted, which is implicitly acknowledged in the OECD-DAC definition, extending diversity and inclusivity in its scope. However, to assess impact in research, this definition must be more operationally defined and adapted to the context to be feasible to use. For this study, the UNDG's definition of impact was used as it accounts for the varying factors that must be considered when determining impact and because the introduction of a SET can be a critical enabling asset that can influence the livelihood strategies and development of rural households the SLA is a valuable tool to use.

2.3 Conceptual Framework: Sustainable Livelihoods Approach

According to Colombo (2018), impact research requires a multi-dimensional approach; therefore, this study required a theoretical framework that would guide the focus towards the understanding impact of SETs specific to livelihoods of rural households in the developing context. The SLA framework was used as a gauge to examine how impact has been characterised in research on SETs. To this end, Sets are widely promoted to have several benefits; the approach used in this study was to examine more precisely the nature of these benefits concerning the SLA. Maxwell (2005) explains that in any study, the conceptual framework is a critical aspect of the design in that it acts as a system of concepts, assumptions, expectations, beliefs, and theories that support and inform all aspects of the research being undertaken. Svinicki (2010: 5) went on to explain that:

> "a framework acts as the foundation for interpreting and understanding the 'causal or correlational patterns of interconnections across events, ideas, observations, concepts, knowledge, interpretations and other components of the experience."

Similarly, Adom et al. (2018:493) state:

> "a conceptual framework illustrates what you expect to find through your research. It defines the relevant variables for your study and maps out how they might relate to each other to make research findings more meaningful, acceptable to the theoretical constructs in the research field. They assist in stimulating research while ensuring the extension of knowledge by providing direction to the research inquiry."

These definitions cement the importance of having a framework guiding the research process and highlights the need for focus and structure in the conceptualisation phases. The systematic layering and linking of different phases of the research process are also important. Concerning the present study, this type of structure is crucial, and the value of the systematic review largely depends on how the relevant concepts of the study are defined. To this effect, there has been an overwhelming amount of support given to promoting development through the coexistence between the economy, technology, people and the environment. In energy provision, several approaches have been developed over time that have recognised the role that access to energy plays in promoting development in this manner, especially in poor and remote communities (Munien, 2016).

A livelihood is defined as a set of activities performed to live for a given life span (Serrat, 2017). A sustainable livelihood 'can cope with and recover from stresses and shocks and maintain or enhance its capabilities, assets, and activities both now and in the future while not undermining the natural resource base' (Serrat, 2017: 21). The concept of 'sustainable livelihoods' emerged in 1987 at the World Commission on Environment and Development and suggested that the narrative around development needed to shift the focus of environmental problems towards people and how they live (Elizondo, 2017). The SLA was developed by DFID (1999b) to be used as an analytical tool to understand the livelihoods of poor communities (Figure 2.8).

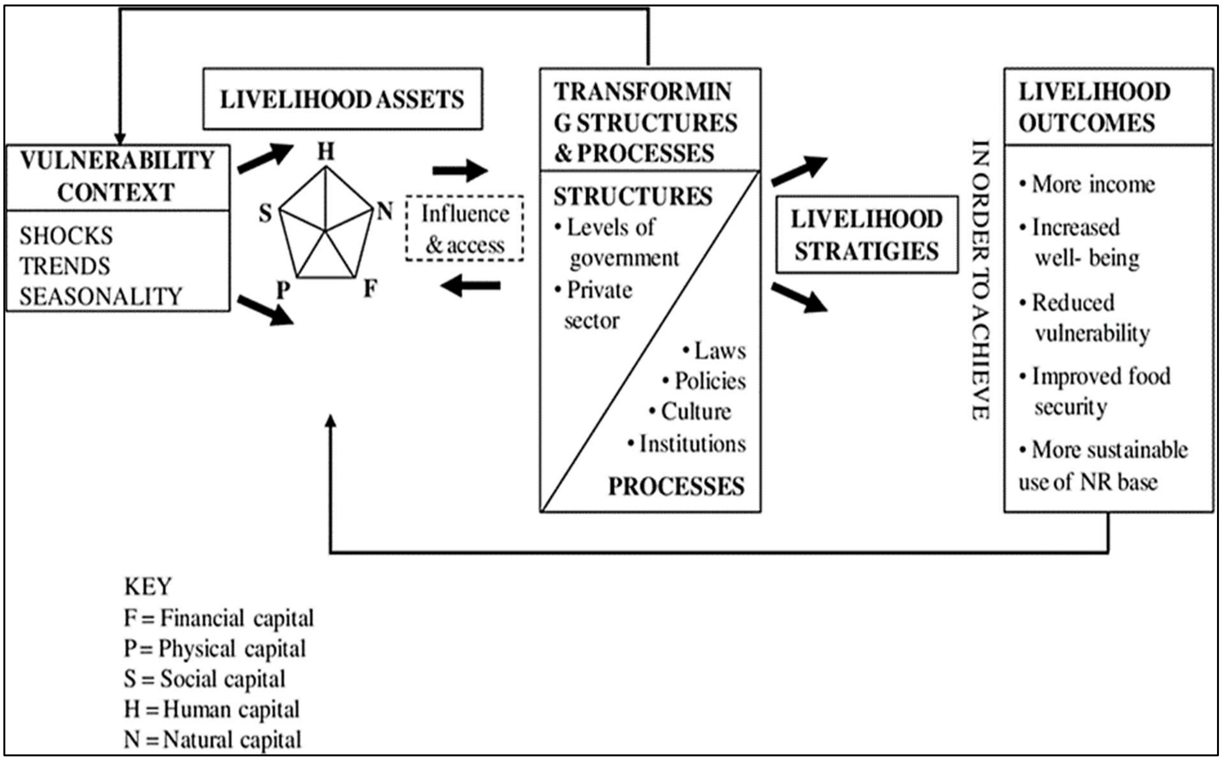

Figure 2.7: The Sustainable Livelihoods Approach framework (Source: Carney et al., 1999: 9)

The SLA model uses five critical aspects of rural development: vulnerability context, capital assets, policies and institutions, livelihood strategies and livelihood outcomes, and elucidates their inter-relations and impacts as illustrated in Figure 2.7. The framework illustrates that for livelihood outcomes to be sustainable and be achieved with minimal trade-offs and compromises, it requires a combined and balanced contribution from the livelihood assets component (Elizondo, 2017). An important aspect is that these assets can be destroyed or created under the influence of the vulnerability context (Nsubuga et al., 2021). The assets are then dependent on the last component of the framework, which is the transforming structures, referring to the society's institutions, organizations, policies, and legislation that shapes livelihoods, unlike other approaches that tackle poverty by identifying and addressing the needs of poor people and attempts to improve their lives by building on what assets they have (UNDP, 1999). At the core of the SLA are the five capital assets needed for a sustainable livelihood. The five livelihood assets are human capital, social capital, natural capital, physical capital, and financial capital. Quandt (2018) explains that despite these five capitals overlapping in certain aspects, they encompass different types of assets needed for sustainable livelihoods, as described by several authors in Table 2.1.

Human capital can vary and is dependent on the quality of labour, which varies according to household size, skill levels, leadership potential and health status, to name a few factors (DFID, 1999b, Serrat, 2017). Apart from the intrinsic value, human capital is required to influence all other forms of capital (DFID, 1999b). Although insufficient as a stand-alone resource, it is vital to achieving positive results in any dimension regarding livelihoods (Elizondo, 2017). Natural capital refers to naturally occurring resources and services used by households to sustain their livelihood (Nsubuga et al., 2020). Natural resources can be tangible or intangible and include land, water, biological, and productive and regulatory environmental goods and services (Department for international development, 1999b). Rural development efforts have primarily centred on increasing natural capital because of the degree to which it is associated with income generation, food production and overall socio-economic well-being (Pandey et al., 2017, Nsubuga et al., 2020).

Financial capital refers to income, credit, debt, savings, and other monetary value assets required in the pursuit of basic livelihood strategies (Serrat, 2017). Financial capital serves to allow households to acquire basic goods and services, healthcare (human capital), food (food security) and education (human capital) (Mazibuko, 2013). Physical capital refers to the producer goods and the infrastructure available to households to implement their livelihood strategies. Examples include roads, schools, communication and information technology, housing and safe water supply (Elizondo, 2017). Several participatory poverty assessments have established that a lack of certain types of infrastructure signifies a core variant of poverty (Gaal and Afrah, 2017). Without access to adequate basic services such as water and energy, quality of life deteriorates, resulting in prolonged periods of livelihood stagnation (Kaygusuz, 2011). Social capital is the network of relationships between households and the community (Pandey et al., 2017). These are based on the claims of trust, support, and mutual understanding to aid each other in pursuing livelihood strategies (Elizondo, 2017). Social capital is defined by the OECD (2001: 41) as "networks together with shared norms, values and understandings that facilitate co-operation within or among groups". These resources can benefit communities and/or social groups, such as providing spiritual well-being, sound psychological state of mind, social status, and civil society (Department for international development, 1999a, 1999b).

Table 2.1: The five livelihood capitals described by various authors (Adapted from: Quandt, 2018)

Capital Assets	Scoones (1998)	Tacoli (1999)	Campbell et al. (2001)	Adato, Meizen-Dick (2002)	Erenstein et al. (2010)	Majale (2002)
Natural	Environmental services, natural resource stocks such as soil, water, air	Freshwater availability, land management, agricultural space, land	Soil fertility, water, forest resources, grazing land	Land, water, forests, marine resources, air quality, erosion protection, and biodiversity	Annual rainfall, soil capability index, farm size, herd size	land, water, wildlife, biodiversity, environmental resources
Economic	Cash, credit, Savings. Basic infrastructure, equipment and technologies	Infrastructure and tools/equipment	Credit, savings, remittances	Savings, credit, inflows of state transfers and remittances	Farm size, herd size, bank facilities, credit societies	regular remittances or pensions, savings, supplies of credit).
Human	Skills, knowledge, ability of labour, good health	Labour including skills, knowledge, ability to work	Knowledge, skills, health, labour availability	Education, skills, knowledge, health, nutrition, labour-power	Female literacy, inoculations, work participation, population density	Health, knowledge, skills, information, ability to labour
Social	Social resources including networks, social claims, affiliations, associations	Access to markets, representation and access to the 'state'	Trust, mutuality of interest, leadership, kin and ethnic networks, organizations	Networks that increase trust, ability to work together, reciprocity. safety nets, organizations	Cooperative societies, self-help groups	Relationships of trust, membership of groups, networks, access to broader institutions).
Physical	Included in financial capital	Included in financial capital	Households assets, agricultural implements, infrastructure	Transportation, roads, buildings, water/sanitation, energy, technology communication	Irrigated area, farm equipment, distance to nearest town, roads	Basic infrastructure-water, sanitation, energy, transport, communication, production equipment

Typically, there are overlaps between financial and natural capital bases since natural capital can generate financial assets. Additionally, there are also trade-offs between the five livelihood capitals. For example, financial capital may be diminished to build up human capital by paying school fees. Weighing the trade-offs between these five types of livelihood capital is an ongoing process for households and individuals. Furthermore, the five capital assets can be constrained by transforming structures and processes into the broader society (Quandt, 2018). Table 2.1, above, lists more detailed descriptions of the capital bases of the SLA, which was used to classify the indicators from the impacts recorded in the studies identified by the systematic review.

According to Majale (2001), the SLA is a holistic approach that tries to capture and provide a means of understanding poverty's fundamental causes and dimensions without shifting the focus on economic issues, food security, and energy poverty. In addition, it tries to draft out the relationships between the different facets of poverty to enable more effective prioritisation of action at an operational level. The SLA essentially aims to help poor people achieve lasting livelihood improvements by understanding how certain activities, skills, social networks and access to assets can impact or livelihood outcomes or a viable livelihood strategy for the rural family (Ellis and Biggs, 2001; Serrat, 2017). Kaygusuz (2011) states that the limitations to the diversification of household livelihood options are attributed to the lack of access to energy services, impacting household income generation and the potential to accumulate assets. Sovacool et al. (2012) assert that an immediate benefit of improving access to energy services satisfies basic (lighting, improved education potential, health and communication), productive (mechanized agricultural production and income-generating opportunities), and modern (cooling, heating and domestic appliances) needs.

The World Bank had previously indicated that the measuring of impacts should be multi-dimensional (Colombo et al., 2018). Therefore, in line with the shift in global narrative, impact research needs to move beyond technical and financial impacts and identify the role of people concerning the influence on means, abilities, and opportunities. In addition, the context or conditions in which individual lives are important because, in the case of energy provision, different contexts may result in different impacts being experienced. In this regard, the Sustainable Livelihoods concept includes all “the capabilities, assets and activities required for a means of living” which inhibit or improve an individual’s ability to make their lives economically, environmentally, and socially sustainable (Serrat, 2017:21). The measurement of livelihoods capitals, and their improvements due to a respective project, had first been proposed within the Renewable Energy for Sustainable Rural Development (RESURL) project, which was developed from a partnership between the Department for international development (DFID) and the Centre for Energy Policy and Technology of the Imperial College London. The aim was to develop a decision support system to select new appropriate sustainable energy solutions in remote areas, based on expected changes of the five community's capitals. However, the indicators chosen to quantify capitals and the analytic procedure to simulate changes of capitals appeared to be unclear and subjective (Colombo et al., 2018).

Wolkas (2010) and Dahlqvist and Larsson (2019) showed how the SLA assets could be used as an analytical tool to determine SET's impact on rural households. Wolkas (2010) adapted the SLA and used the framework to develop appropriate indicators based on the linkages between household assets and SWH interventions. Similarly, Dahlqvist and Larsson, 2019, used the sustainable livelihoods framework (SLF) to understand better how capital assets are being impacted to get a holistic understanding of how off-grid solar energy has impacted rural households in SSA. Wolkas (2010) linked employment, time-saving, mental health, and access to information as indicators of impact on human capital. While Dahlqvist and Larsson, 2019, analysed the impacts on human capital in terms of children's capability to study and academic performance, the health of women and children, human capability concerning productivity, skills, and knowledge. Indicators of impact on natural capital included greenhouse gas emissions, indoor air quality, deforestation, use of biomass, and battery disposal. Wolkas (2010) includes financial support or general assistance in maintaining the installed SET as an indicator of financial capital.

In comparison, Dahlqvist and Larsson (2019) divided financial capital assets into three aspects relating to the impact on savings of the household, the income of the family and the expenses related to solar energy. Both studies looked at the impact on social capital regarding the household's relationship with neighbours and outsiders. While the impact on physical capital was determined by changes to household infrastructure, the ability to charge mobile phones, improvements in communication, and strengthen or enhance producer goods of the household (Wolkas, 2010; Dahlqvist and Larsson, 2019). Additionally, capacity building in the energy sector centres around the operational and maintenance know-how of existing energy infrastructure, highlighting the influence of skills and technical capacities of potential energy users (Stephenson et al., 2010). Training, awareness and skills development will serve to improve on multiple capital assets available to the household (Mulugetta, 2008). Chaurey et al.

(2004) show that the provision of electricity improves human capacities and, therefore, has a direct impact on the local Human Development Index (HDI).

Sustainable livelihood activities impacted by SETs are significant in poor communities that have to identify and implement effective ways to support their livelihoods and escape poverty. Additionally, access to energy sources (whether in the form of electricity, traditional biomass or renewable sources) can be viewed as a key enabling asset or resource at the household and community level (Kaygusuz, 2011). The absence or presence of this resource can, in turn, influence the quality of life and livelihood strategies (Barnes et al., 2017). Therefore, it is important to determine how these livelihood impacts are determined and what impacts SET's are having, be it positive or negative, as it effectively indicates whether or not they are the appropriate technologies to be installed to combat energy poverty in these communities. Colombo et al. (2018) reinforce this by underscoring the importance of the context in which the individual lives since this influences energy provision and may result in different impacts.

Similarly, this study seeks to use the SLA to classify the indicators used in the reviewed studies according to their relation and influence of the capital assets and to interpret the research elements. The strengths of the SLA are primarily the framework's versatility and that it draws attention to the assortment of assets that people utilize when constructing their livelihoods. Furthermore, the approach accounts for changing combinations of livelihood activities in a dynamic and historical context (Serrat, 2010). It moves beyond a focus on monetary measures to more adequate multi-dimensional understandings of livelihoods (Rakodi, 1999). Despite being critiqued for not sufficiently accounting for power relationships and politics (Scoones, 2009), underestimating macroeconomic trends and conflict, a lack of rigorous attempts to deal with long term change, and being expert-driven (Quandt, 2018), the value of the SL approach is that it encourages a broad systematic view of the factors that enable and/or constrain livelihoods.

Therefore, to capture the multiple dimensions of energy-centred rural development, a more nuanced approach to research is required. Madubansi and Shackleton (2007) state that previous approaches that failed to address the root causes of poverty and capture the immediate needs of the poor did not bring about positive outcomes in livelihoods and simply perpetuated poverty cycles. Similarly, these issues may appear in impact research with regards to SETs. In addition, improved energy security significantly reduced household vulnerability to shocks, stressors, and seasonal variability. Therefore, the evaluation of the impacts these technologies have on rural households should combine aspects simultaneously and take into consideration all possible effects on the human, social, environmental, economic/financial and institutional contexts. Disregarding the interdependent nature of energy with other issues would result in unsuccessful or inefficient impact assessments (Brent and Rogers, 2010).

2.4 Conclusion

This chapter offered a summary of the changing themes in the energy discourse and the state of SET's in developing countries. This included the barriers to the expansion of the solar industry in developing countries. This chapter also included an overview of the energy profile of rural households and factors that influence household energy behaviours, and choices were also present. The literature presented in this chapter provides the status quo for data analyses and concluding remarks emanating from this study. The chapter concluded with a critical description of the conceptual framework that underpins this study, i.e., the Sustainable Livelihoods Approach.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

The following chapter describes the chosen research methodology guided by the study's aims and objectives. The study is a pragmatic, longitudinal, sequential exploratory mixed-method approach that uses a systematic review method to consolidate the archival research published on SET impacts on rural households in the Global South within a temporal range from 1999 to 2019, as it accounts for the developmental paradigm shifts in terms of the MDG's and subsequent establishment of SDG's that impacted the energy sector. In addition, this chapter provides an overview of the meta-analyses approach used to profile the impacts of SETs across the developing context, which is the geographic and socio-economic focus of the study. Developing countries house a large proportion of the world's poor, and, within this context, SETs are targeted because they offer multidimensional benefits (quality of life, health, basic services). The focus on the Global South was strategic since this study examined the impacts of SETs on livelihood outcomes.

3.2 Geographic and socio-economic focus

Global South is not exclusively a geographic term and was first used in 1969 by Carl Oglesby to describe the dominance that the north had over the south, which led to gross inequalities. Over time, the term gained popularity and emerged as an identity that would unify the Global South countries (Figure 3.1). Some scholars have preferred to use the term 'developing countries' or 'Third World', but at present, the World Bank classifies the Global South countries according to low or middle income (Silver, 2015). The Global South comprises approximately 134 countries from Africa, Latin America and the Caribbean, the Pacific Islands, Asia, and the Middle East. According to their land area and population, Brazil, India, China, Indonesia, and Mexico are the largest Global South countries (Silver, 2015). The Global South countries share a common history of past colonisation and the resultant socio-economic challenges, including poverty, food shortages, high unemployment rates, and excessive population growth (Dados and Connell, 2012). Despite this, Global South countries, Brazil, Russia, India, China, and South Africa have emerged as the fastest-growing economies globally, which has allowed for their significant influence on regional and global affairs (Puri, 2010).

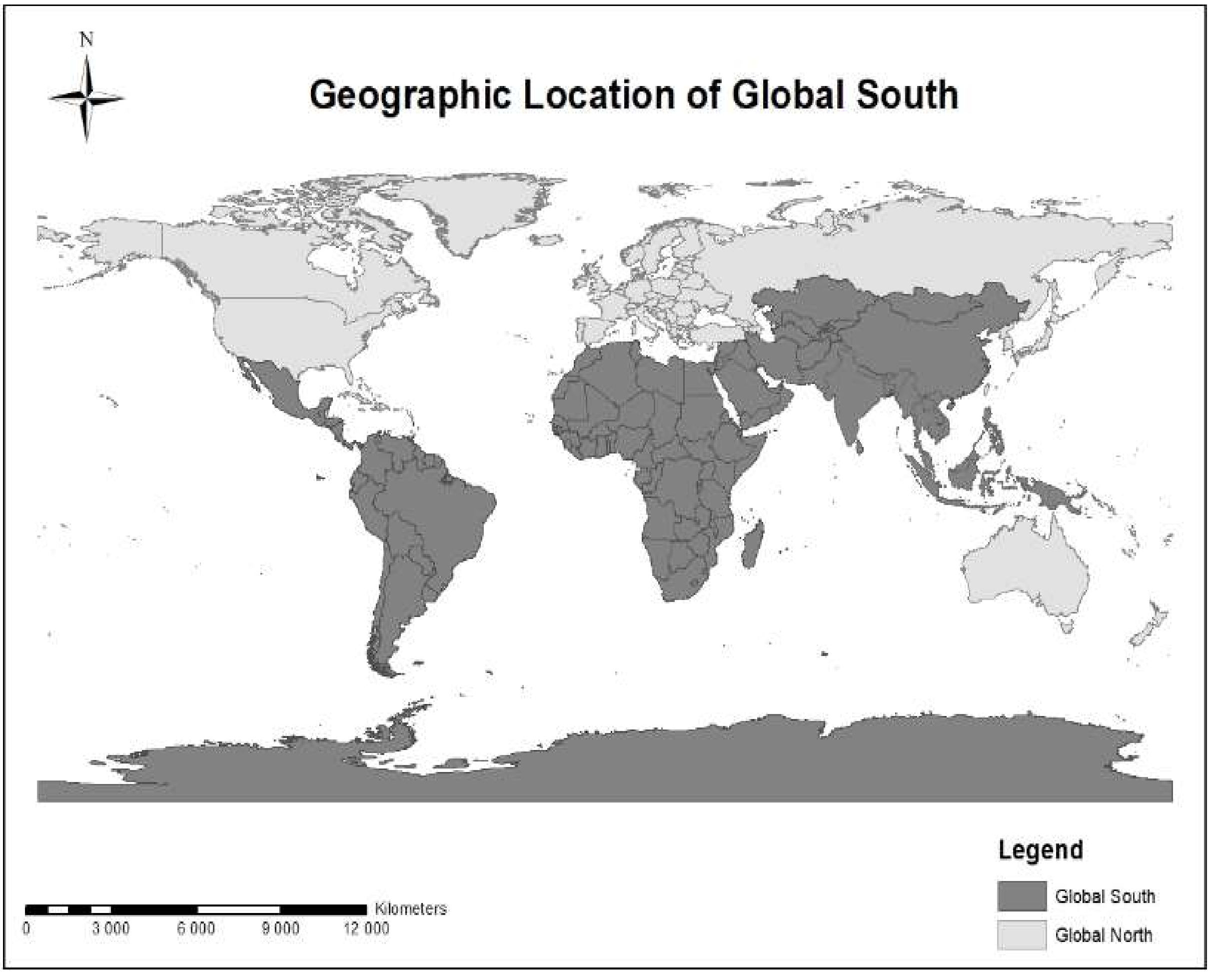

Figure 3.1: Geographic scope of Global South countries (Author, 2019)

Of more importance is that the vast majority of SETs are implemented to resolve poverty, including energy poverty (Obeng and Evers, 2009, Barnes et al., 2011, Lee and Shepley, 2020). The literature further highlights the role that these technologies can play in improving health and sanitation (Samad et al., 2013; Hakiri et al., 2016), quality of life (Wijayatunga and Attalage, 2005), and income-generating options (Millinger et al., 2012; Huq, 2019). In this regard, extensive research examining the experiences and impacts of these technologies. In retrospect, few studies characterise these impacts concerning livelihood outcomes within developing countries. It is believed that this characterisation could potentially inform energy policy and energy development agendas by highlighting the suite of technologies associated with livelihood outcomes. In addition, developing countries such as South Africa are investing significant resources in RETs that can serve both environmental (climate change) and socio-economic goals. In this regard, systematic reviews such as this study that examines the developing context can be a useful tool. The research questions that framed the study are listed in the section below.

3.3 Research questions

This study has been informed by the research aims and objectives outlined in Chapter One, which sets out to determine how research on the impacts of SET's on rural households in the Global South has changed over time using a mixed methodological approach. The following research questions have been formulated to guide this research:

- How does the number of publications produced in the global north differ from that of the Global South?
- How does the number of publications change over time?
- How does the type of studies conducted vary, and how have they changed over time?
- What SET's have been investigated over time?
- What is the geographic scope of the publications that were reviewed?
- What indicators have been used to determine impact?
- How diverse and inclusive are the indicators when classified according to the SLA?
- What impacts are SET's having on rural households according to the most frequently used indicators?
- How do the methodologies used vary, and how have they changed over time?
- Is the quality of the reviewed articles of a satisfactory standard from which to conclude?

3.4 Research Methodology

Rajasekar et al. (2006) stated that a research methodology is a systematic approach to conducting research that involves detailed insight into the chosen tools and procedure to solve a problem. Wrench (2017) described research methodology as to how research should be conducted to understand and structure scientific knowledge and the knowledge-creation processes. More recently, Sileyew (2019) described a research methodology as the path through which these researchers formulate their problem statement and objectives and how best to present and analyse the study results. According to Chilisa and Kawulich (2012), choosing a methodology begins with choosing the research paradigm, an essential step in assessing whether the assumptions are appropriately aligned to inform the study. This study uses the research onion model (Figure 3.2) by Saunders et al. (2012) to explain the overall research process adopted.

Studies show that the logical and systematic processes involved in data collection and analysis enables the researcher to produce new and valuable information on the chosen phenomenon, whereas the philosophical paradigm determines which knowledge should be accepted or rejected (Rajasekar et al., 2006; Leedy and Ormond, 2010). This study examines the impact that SET's have on rural households in the Global South. The conceptual framework utilized in this study will also aid in examining the information from the reviewed literature. The following sections will offer a comprehensive explanation of and motivation for the chosen research design, methodological approaches and tools. In addition, it will provide the philosophical paradigm that underpinned this research project and the methodology used.

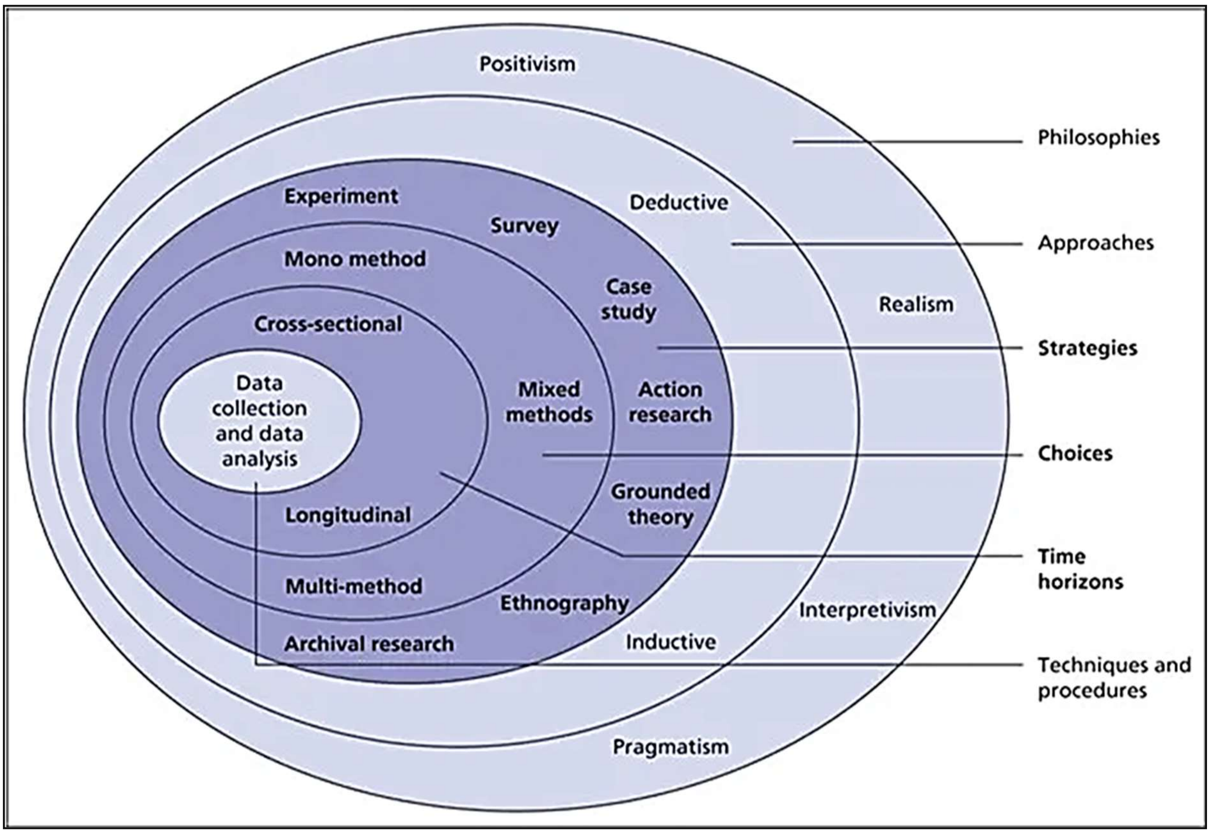

Figure 3.2: The research onion model (Source: Saunders et al., 2012: 32)

3.4.1 Research philosophy and approach

Research philosophy is a systematic guide to researching a given phenomenon, resulting in reliable knowledge about the research endeavour being undertaken. In other terms, it is the foundation of the research, which involves the choice of research strategy, formulation of the problem, data collection, processing, and analyses (Žukauskas, 2018). This study is located within a pragmatic philosophical paradigm centred on the premise that academics ought to use the philosophical and/or methodological approach that works best for the research problem under investigation (Sahay, 2016). Pragmatics recognise that:

> "…there are many different ways of interpreting the world and undertaking research, that no single point of view can ever give the entire picture and that there may be multiple realities."
>
> (Saunders et al. 2012: 4)

According to Kaushik and Walsh (2019), pragmatic research philosophy deals with the facts and considers the consequences of research and the research questions of higher priority than the methods. Pragmatist researchers utilize various data collection techniques and analysis procedures because, in contrast to positivism and interpretivism, pragmatic research can integrate more than one research approach, research strategy and research method within the same study (Sahay, 2016; Kaushik and Walsh, 2019). For this research study, the following research concepts according to the onion model (Figure 3.2) was included and will discuss in detail in subsequent sections below:

- Pragmatic research philosophy utilising an inductive and deductive research approach
- Archival research strategy
- Mixed method research choice that includes qualitative and quantitative methods
- Longitudinal time horizon
- The techniques and procedures included a systematic review for data collection and a meta-analysis for data analysis.

Kaushik and Walsh (2019) warned that pragmatism raised methodological concerns by some researchers in that it justifies the employment of multiple methods, measures, researchers, and perspectives. In contrast, many scholars argued that pragmatic research does not afford a philosophical foundation for mixed-methods research; instead, it is realism that offers a more valuable viewpoint for many aspects of mixed-methods research. Consequently, this study utilizes a mixed-method approach, discussed below in detail.

3.4.2 Mixed methods: Qualitative and Quantitative

Mixed method approaches are emergent methodologies that advance the systematic integration or 'mixing' of quantitative and qualitative data within a single investigation (Creswell, 2003). Berman (2017) described mixed method research as the 'third methodological orientation' because it combines qualitative and quantitative research strengths. Quantitative research is utilised when there is a need to quantify a problem by creating numerical data or data transformed into functioning statistics (Chambers and Hastie, 2017). It is used to measure attitudes, opinions, behaviours, and other well-defined variables. In addition, quantitative research methods are used to generalize results from a larger sample population. Essentially quantitative processes measure and examine patterns and relationships within data (Munien, 2016). Quantitative research is regarded as a deductive approach since it is objective and can generalize and predict results using unbiased numerical data (Harwell, 2011).

In contrast, qualitative research is considered by its aims which relate to the in-depth understanding, characteristic of social life and its methods, which produce words instead of numbers for data analysis (McCusker and Gunaydin, 2015). Qualitative research is predominantly exploratory and is used to understand underlying experiences, perspectives, reasons, thoughts, and motivations (Venkatesh et., 2013). This method is generally described as inductive since the underlying assumption postulates that reality is socially constructed and that variables are complex and interrelated, therefore, difficult to quantify (Almalki, 2016). Thus, mixed-method research involves a purposeful mixing of approaches in data collection, data analysis and interpretation. According to Shorten and Smith (2017), an advantage of using a mixed-method approach is integrating the two different types of data that allows researchers to seek a more robust view of their research landscape. In addition, it provides researchers with the opportunity to compensate for any inherent weaknesses and enables the researcher to offset inevitable method biases (Greene, 2007).

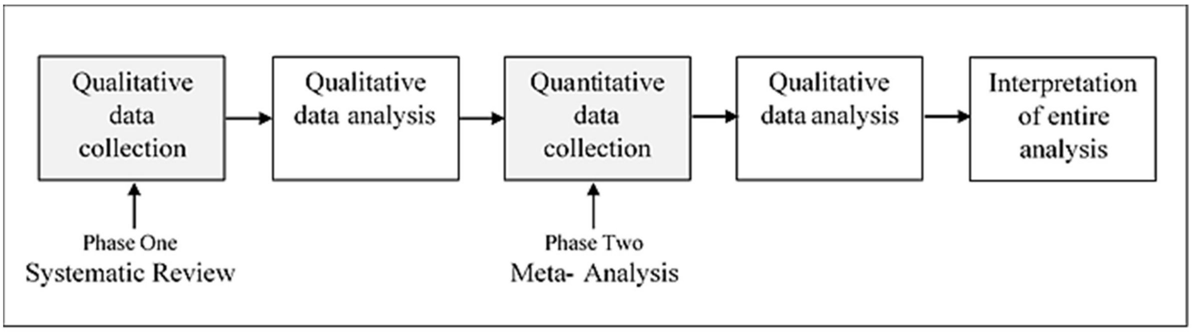

Figure 3.3: Sequential exploratory mixed-method design (Adapted from: Hesse-Biber, 2010)

Mixed methods research uses quantitative and qualitative research methods, either concurrently (i.e., independent of each other) or sequentially (e.g., findings from one approach inform the other), to understand a phenomenon of interest (Venkatesh et al., 2013). Creswell (2003) identified six mixed-method designs: sequential explanatory, sequential exploratory, sequential transformative, concurrent triangulation, concurrent nested design, and concurrent transformative.

For this study, the approach adopted can be described as sequential exploratory, which combines qualitative and quantitative data collection and analysis in a sequence of phases. This study uses a systematic review to collect qualitative data from 56 publications investigating the impacts of SETs on rural households in the Global South. Thereafter, a meta-analysis was conducted to interpret the qualitative data to determine how research on the subject changed over time and the recorded impacts of SETs which created numeric data (Figure 3.3). According to Mihas (2019), in the initial stage, the researchers collect qualitative data and then analyse the data, which direct the next quantitative phase, which could be a survey or some other form of quantitative data collection. Similarly, Creswell (2003) described the sequential exploratory mixed method approach as the qualitative data collected first and then quantitative, where the quantitative results complement and extend qualitative findings. To this effect, the use of the systematic review of secondary data or an archival research approach complemented the sequential exploratory approach by identifying the available literature needed to address the research questions directly and achieve the aims and objectives of this study. The archival research is discussed in further detail below.

3.4.3 Archival research

Archival research is an underestimated and rarely used method of research (Das et al., 2018). In a literal sense, the archival method translates to methods that comprise the study of historical documents or documents created at some point in the relatively distant past. However, recently, archival methods have been utilised by scholars undertaking non-historical examinations of documents and texts created by and about contemporary organizations, often as tools to supplement other research strategies (Ventresca and Mohr, 2002). Presently, when referring to an archive, it is understood simply as a record or compilation; an archive can contain a wide variety of primary source material (Allen, 2017). With this understanding, archival methods can also be applied to analysing manuscripts, documents, records, digital texts, including electronic databases, emails, and web pages (Mohr and Ventresca, 2002). For this study, electronic internet databases, Web of Science, WorldCat and the Google Scholar search engine containing published articles on various topics were used to identify articles relevant for review. Over time archival research has become less time consuming and more efficient when searching archival indexes use technology (Harris, 2001).

According to Das et al. (2018), the primary and most apparent advantage of archival data is the ease of availability and accessibility, which amounts to a minimal cost to the academic. There are arguments over the role of archival data in contemporary-oriented research, to which Das et al. (2018: 139) responds:

> "Archival data can be used to increase 'empirical depth' in a project by creating new data and allowing for authentication of existing data from other sources; archival data are particularly suited to producing developmental explanations, in other words, explaining processes of change and evolution; and archival data can be used to challenge existing theories and build new theoretical models."

Furthermore, archival research allows researchers to find further research opportunities by drawing attention to disappearing resources and identifying gaps in knowledge (L'Eplattenier, 2009). Based on the findings of Timothy (2012) and Das et al. (2018), the following disadvantages to archival research were identified, (1) selected sources or publications may not have all the variables that are of interest, (2) the quality of the source or publication may be compromised by missing data points and misrepresentations which can result from human error, (3) archival data are vulnerable to researcher bias which can be as a result of the researcher being tempted to examine the data and accordingly formulate convenient hypotheses. Lastly, (4) a disadvantage of archival research is that there may be restricted access to documents or publications, making it difficult to obtain. Harris (2001) identified another disadvantage in that a researcher with no sense of the project aims and objectives will have extreme difficulty finding what they are looking for and will be "swallowed by the archive". Notwithstanding these limitations, a wealth of published research can be strategically harnessed to address new questions and create new knowledge. The worth of such is primarily embedded in the manner in which data is extracted and classified. The data collection processes are critical; these aspects are discussed in the subsequent sections.

3.4.4 Data collection tools and processes

For this study, secondary sources were identified through a systematic review method. The secondary data sources comprised peer-reviewed journal articles and reports on the impacts of SET's on rural households in Global South countries. These records were examined, and based on a predefined criterion (discussed later), critical information was extracted and used to populate a database. The subsequent sections will describe the criteria that informed the selection of studies, the extraction of the data from those published studies, and the software used to meta-analyse the data.

3.4.4.1 Systematic Review

Crocetti (2016) defined a systematic review as a review of a defined research question using an explicit method to identify, select and appraise research from which the data is extracted and analysed. Similarly, Ahn and Kang (2018) describe systematic reviews as a critical overview of the primary research undertaken on a specific topic, carried out methodically to collect all possible studies related to a given. Due to the exponential growth of the scientific literature, review articles are presently acknowledged as a significant source of information (Linares-Espinos et al., 2018). The quality of studies is evaluated during the systematic review process, and a statistical meta-analysis of the study results is conducted based on the number of citations (Ahn and Kang, 2018). In this way, systematic reviews can potentially aid in decision-making processes, identify inefficacies, summarise the magnitude of benefits and risks, and identify knowledge gaps (Impellizzeri and Bizzini, 2014). These research methods effectively overcome the complexities of doing large-size randomized controlled trials (Crocetti, 2016). However, poorly designed systematic reviews and meta-analyses could yield misleading results (Ahn and Kang, 2018).

Several protocols or guidelines have been suggested for conducting systematic reviews to ensure that it is meticulously planned with all steps adequately documented. This ensures quality and replicability and promotes the researcher's transparent conduct, accountability, and research integrity (Moher et al., 2015). The guidelines used for this study is the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA, 2009 and 2020). The PRISMA guideline was created to assist researchers in establishing suitable protocols for systematic reviews and meta-analyses by establishing the minimum requirements. Subsequently, the release of the 2020 guideline allowed for the inclusion of more than one database. Bramer et al. 2017 state that when conducting a systematic review, it is advisable to use a combination of databases to increase the yield of related literature.

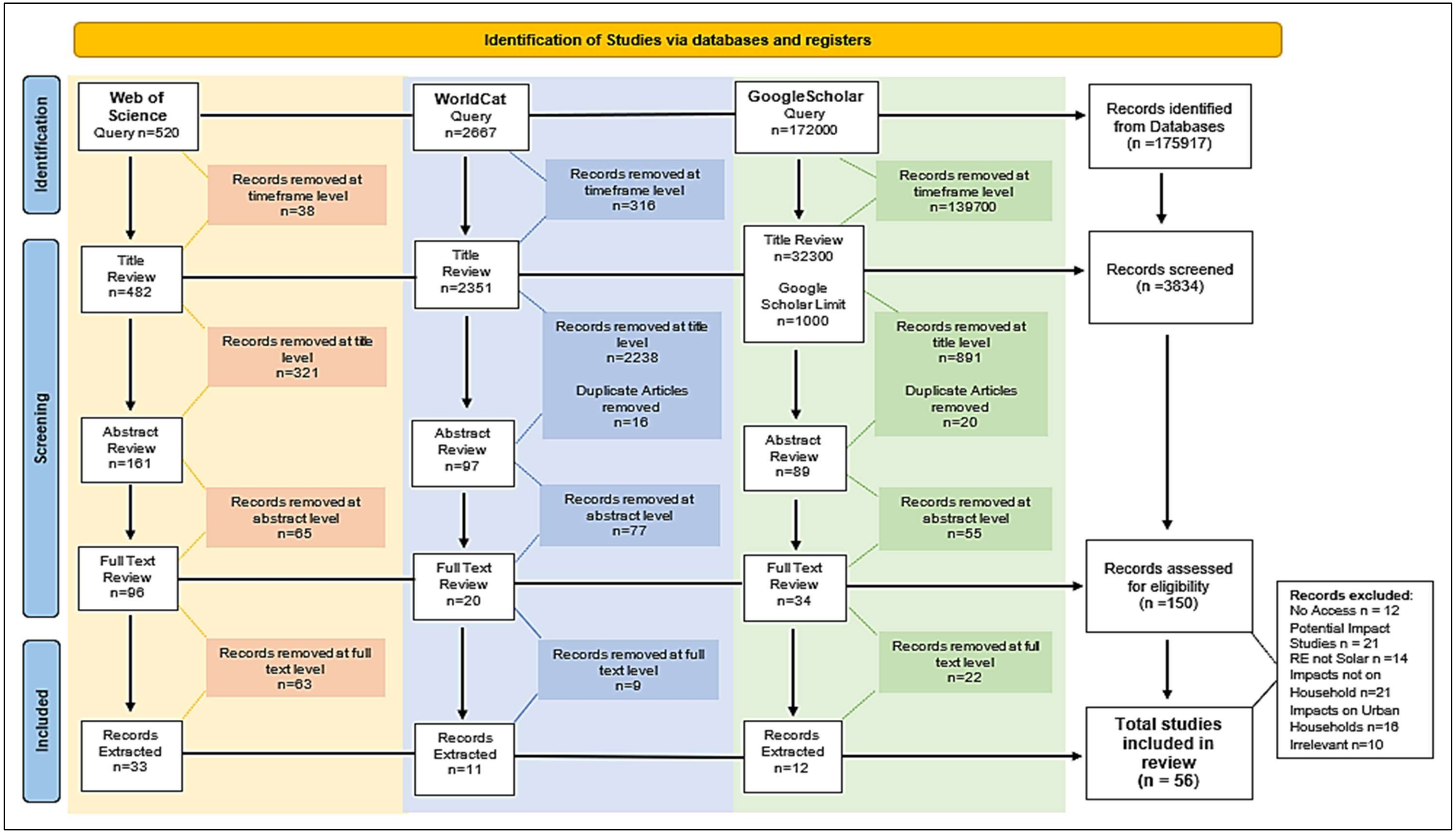

Figure 3.4: Diagrammatic representation of the systematic review process

For this study, three databases were used, namely Web of Science, Google Scholar and WorldCat (Figure 3.4). Web of Science was utilised for the search as it contains several databases that index the world's leading academic literature across a range of disciplines. Bramer et al. (2017) determined that to yield the optimal results in a systematic review, researchers should search at least Web of Science and Google Scholar as a minimum requirement to ensure ample and efficient reportage. This is due to the ability of Google Scholar to collate both academic and grey literature, which broadens the scope for systematic reviews to include literature not published by commercial publishers (Haddaway et al., 2015). However, due to Google Scholar's low recall capabilities related to the limit on search results, WorldCat, the world's largest network of library content and services, was also utilised. Other studies show a similar approach, whereby a systematic search of more than one multidisciplinary database was used (Khan et al., 2015; McCabe et al., 2018; Munro and Cairney, 2020). Figure 3.4 illustrates the systematic procedure followed whereby the initial search across each of the three databases and registers, Web of Science (n =520), WorldCat (n =2667) and Google Scholar (n=172000), yielded 175917 records in total.

The search criteria were standardised across all three platforms and were conducted using key terms and controlled vocabulary focused on the themes 'solar', 'impact', and 'household'. Since there is considerable variation in the definition of impact, the author solely used the keyword 'impact' in keeping with the UNDG's definition of impact and account for varying definitions of the term adopted by researchers. For consistency, the exact search words were used for the Web of Science and WorldCat database searches. However, in the case of Google Scholar, the syntax of the search was 'Solar+impacts+household'. The search strategy was conducted in three phases: database identification, screening, and inclusion for each of the databases (Figure 4.3). The initial search using the key terms resulted in 175917 English-language publications being identified. The results were then filtered to show scientific peer-reviewed articles, impact reports, and book chapters published or made available on the database between 1999 and 2019. At the timeframe scale, a total of 140054 records were removed.

The critical inclusion criteria for this review were: i) clearly defined post-installation impacts of SETs on ii) rural households in Global South countries. Therefore, after the selection of the timeframe, all titles were examined. At this stage, if the titles listed countries outside the geographic scope, focused on other RETs instead of solar-based ones, and records focusing on pre-installation case studies were removed from the database. While all article titles were screened in both Web of Science and WorldCat, due to their policy Google Scholar automatically limited its search results to 1000, eliminating 31300 potential reports. This type of limitation was found to be commonplace. Upon verifying this limitation, most of the literature suggests that much like this study did, an additional database is searched to overcome the low recall capability of Google Scholar (Boeker et al., 2013; Haddaway et al., 2015 Gusenbauer and Haddaway, 2020). Therefore, at the title review stage, a total of 3834 publications were reviewed, of which 3450 did not meet the inclusion criteria, and 36 duplicate studies were removed. The remaining 347 publications were then subjected to an abstract review in which articles were removed if there was no mention of determining or investigating the impact, effect, or influence of a SET on a rural or low-income household in a developing country. The final stage of the protocol involved a full-text review of 150 publications through which the inclusion criteria of this study was still applied due to misleading titles, abstracts and human error. Therefore, publications were removed if potential impacts were investigated, if the impacts investigated were not on rural households, and if the RE mentioned in the title and abstract was found not to be solar. In addition, due to time constraints, publications were also removed if there was no access to the publication or author permissions were required to access the study

The result of this stage was a total of 56 records that were found to be relevant for this review study from Web of Science (n=33), WorldCat (n=11), Google Scholar (n=12). A matrix was established for the full review phase to extract data (Figure 3.5) objectively and systematically. The matrix categorised records based on the following broad thematic areas:

- Meta-information
- Household demographics
- Household energy profile
- Nature of SET impacts

These broad thematic areas were established based on the categories reviewed studies reported against and the relevance of the information in meeting the aims and objectives of this study. In addition, the number of citations for each study was recorded. This methodical categorisation of the records as part of the full review process is characteristic of the systematic review process, which involves selecting, evaluating, and synthesizing all available evidence. The final stage of this study design is described in detail in the following section.

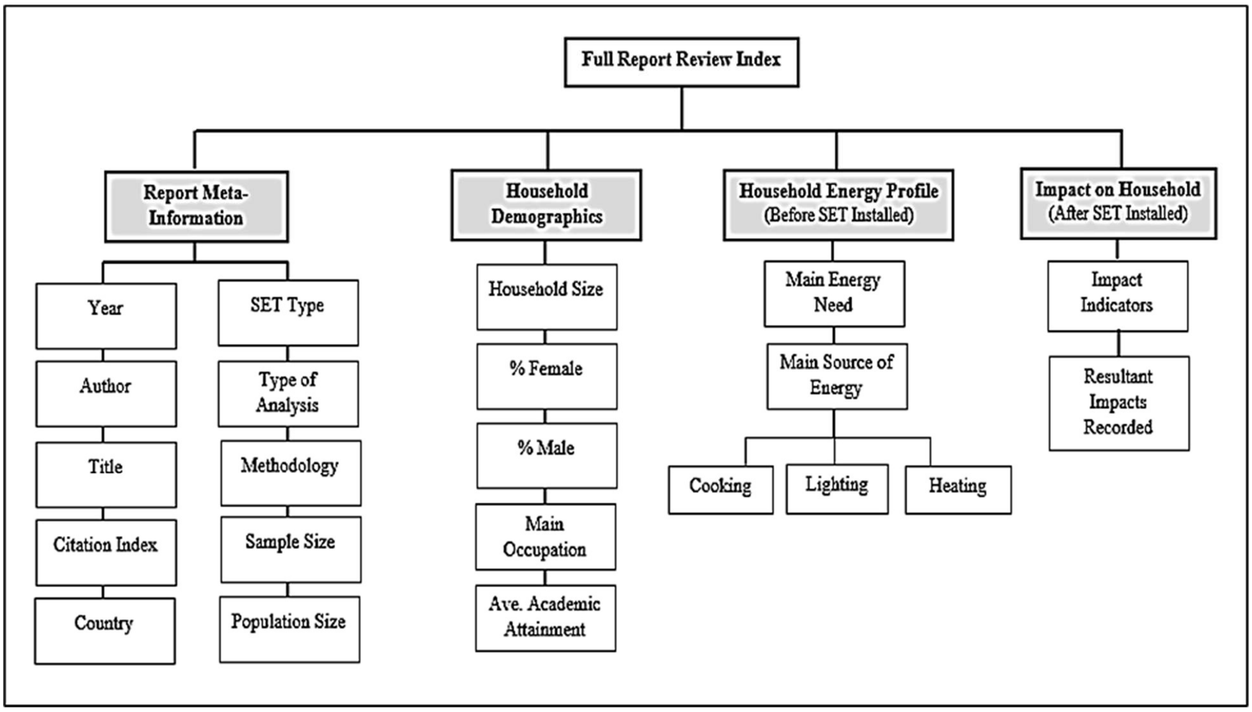

Figure 3.5: Index for full report review meta-data extraction.

3.4.4.2 Meta-Analysis and classification

The concept of meta-analysis refers to a valid, objective, and scientific method of analysing and combining different results (Ahn and Kang, 2018). An alternate definition describes a meta-analysis as using statistical techniques in a systematic review to combine data from individual studies to determine new statistical conclusions (Crocetti, 2016). Similarly, Haidich (2010) described meta-analyses as a quantitative, formal, epidemiological study design used to systematically assess previous research to derive conclusions about that body of research. Since the 1970s, meta-analyses have had a radical influence across numerous scientific disciplines, assisting in determining evidence-based practice and resolving contradictory research outcomes. However, meta-analyses differ from systematic reviews as it utilizes statistical methods on estimations from multiple studies to form a collective estimate (Gurevitch et al., 2018). Not all systematic reviews include meta-analyses, but all meta-analyses are found in systematic reviews. However, the quantitative synthesis of results from a series of studies is meaningful only if these studies have been identified and appropriately collected and systematically (Impellizzeri et al. 2020); therefore, systematic reviews always precede the meta-analysis.

In addition, Impellizzeri et al. (2020) state that a meta-analysis is not just a statistical tool but qualifies as an actual observational study, and hence it must be approached following established methods involving well-defined steps. For this study, the impacts recorded by the studies included in the review will be statistically analysed to determine the mean impact and the percentage of positive or negative impacts recorded amongst them to determine a consensus of the impacts experienced by rural households as a result of installing SETs. The framework used to classify the indicators from the impacts recorded was informed by the UNDG's definition of impact and classified according to the SLA framework. The UNDG's definition considers multiple factors and levels in which impact can occur. The first aspect relates to who was impacted; in this study, it is rural households. The second aspect is to determine what was impacted (health, skills, behaviour). The third aspect is the type of impact (economic, environmental, technological, socio-cultural). Given that the focus of this study was rural households and the UNDG's definition and examples provided extend across livelihood factors, the SLA framework was used to determine how inclusive and diverse the research was in relation to the capital assets. The impacts were then categorised based on how the five capital asset bases were impacted.

The impact is described in the UNDG's definition as positive or negative long-term effects of the intervention, either direct or indirect and intended or unintended. Based on the impacts recorded in the reviewed literature, it could only be established if the impact was direct or indirect and based on the mean calculated, it could be determined whether the impacts of SETs on rural households were positive or negative. An indicator was classified as direct if the impact recorded directly influenced the increase or decrease of the capital base. The indirect indicators were identified if the impact occurred through a series or sequence of events that eventually lead to the increase or decrease of one of the five capital bases. Lastly, the indicators were classified as qualitative or quantitative based on how the impacts were determined or measured.

3.5 Data Analysis

According to Vosloo (2014), data analysis refers to a process that seeks to present data intelligibly and interpretable to identify trends and relationships in the data to address the research aims. An earlier definition by Marshall and Rossman (2014) similarly described data analysis as the process of organising and providing meaning to the mass of collected data. Data analysis is not a linear process but the systematic process of identifying, isolating, and examining variables resulting in complex structures (Baur,2019). There are many different data analysis methods, depending on the type of research. For this study, data were analysed thematically using quantitative and qualitative techniques in two distinct stages; descriptive analyses that provided an overview of the trends and statistical analyses comprising inferential statistics to compare and quantify trends and relationships.

As Web of Science was only one of the three databases that could classify search results according to the country form it was published, the data based on the initial search was used to create a graph to compare the number of publications produced per country. This data was then analysed to determine the difference in the number of publications produced by the global north compared to the Global South. From each initial database search, a descriptive analysis was done of the percentage of publications produced per year from 1999 to 2019 to identify the relationship between the research produced and time. In addition, the initial search results were analysed by category for each database to establish the most prominent research fields. The qualitative data obtained from systematic review from the selected articles were organised into an excel spreadsheet according to the year of publication.

To determine the quality of the reviewed articles, a citation analysis using the highest citation index recorded for each publication from either Google Scholar or Web of Science as WorldCat does not have a citing index. The number of articles published per year was calculated and compared to reflect proportionality over time. Similarly, temporal variations for elements of the research design were estimated using the techniques above. A descriptive analysis was done to determine the development of SETs using those identified in the research over the temporal range of this study. In addition, a time series was plotted to show the relationship between the annual proportion of reviewed studies and significant events affecting the global energy narrative. A spatial analysis was done to depict the geographic distribution of the reviewed articles based on the number of publications and the countries in which the studies took place.

The resultant map was generated using ArcGIS software (Version 10.4) to show the distribution and proportion of studies undertaken in developing countries.

Thereafter, the indicators used to determine impact were themed and recoded and then classified according to whether they were a qualitative or quantitative measure of impact; direct or indirect, the type of SET, and which capital asset base was impacted in relation to the SLA. The classification of indicators was based on whether direct and indirect impacts to the capital bases were reported. Similarly, the impact indicator was classified according to which capital based was impacted. This was done to determine diversity and inclusivity and unpack how the research was undertaken to determine the impacts of SETs on rural households. To establish a consensus on the impacts SETs have on rural households, the mean impacts were determined from the percentage of positive or negative results obtained from indicators that appeared in the reviewed publications (Appendix B). However, due to the lack of reported data and the inconsistency in metrics, some mean results were omitted because they could not be determined.

3.6 Conclusion

A general overview of the Global South and its constituent countries were detailed at the start of this chapter. This was followed by an in-depth description of the research methodologies used in this study and the key philosophical paradigm to the research design. The pragmatic research philosophy promotes the integration of more than one research approach, research strategy, and research method within the same study, thus advocating the use of mixed methods for data collection. In addition, this chapter contained a detailed account of the systematic review and meta-analysis process undertaken in the collection and analysis of the data. The following chapter presents the quantitative and qualitative results, followed by a discussion of significant findings.

CHAPTER FOUR
DATA DESCRIPTION AND ANALYSIS

4.1 Introduction

Solar technologies have become an emerging market globally, emphasising the potential role in addressing energy poverty, climate change mitigation and socio-economic well-being. In this regard, this study aimed to determine how research on the impacts of SETs on rural households in the Global South has changed over 20 years, examining the main types of SETs dominating the markets and the documented livelihood impacts using a systematic review and meta-analysis approach. The selection protocol identified 56 records, which are discussed in detail within this chapter. This chapter comprises quantitative and qualitative findings that are further unpacked using descriptive and inferential statistical analyses. The chapter has the following sections:

- Preliminary findings of the systematic review
- Results of the systematic review and critical analysis of chosen literature
- Meta-analysis of findings generated from the established framework

The following sections present the results from the descriptive analyses reflecting the number of publications, percentage published per category, proportionality based on document type, and geographic focus. This is followed by an analysis of the results from the systematic review focusing on specific categories. The final section of the chapter focuses on the classification of indicators used over time in relation to the sustainable livelihoods theory. Furthermore, this section includes the mean results calculated to determine the impact of SET's from the reviewed literature.

4.2 Results and discussion

This section contains the preliminary findings, an in depth analysis and discussion of the reviewed literature. A total of 56 records were identified through the selection criteria for full review and examined based on the established framework (Appendix A). This followed by the analysis of the indicator classification and meta-analysis of impacts recorded.

4.2.1 Preliminary findings of the systematic review

The geographic representation of research being produced on the impact of SET's on households was found to range across both developed and developing countries (Figure 4.1). As illustrated in Figure 4.4, there is a higher proportion of publications emanating from developed countries. Of the data generated from the initial Web of Science search, only six Global South countries were found to be in the top twenty countries to be contributing research on the impacts of SETs on households. The United States of America had the highest percentage of publications produced (21%), followed closely by Australia (12%) and England (11%). Interestingly, China (7%) and India (6%) emerged in the top five countries while South Africa and Brazil ranked 9th and 13th respectively despite these technologies being promoted in these contexts to have several socio-economic benefits.

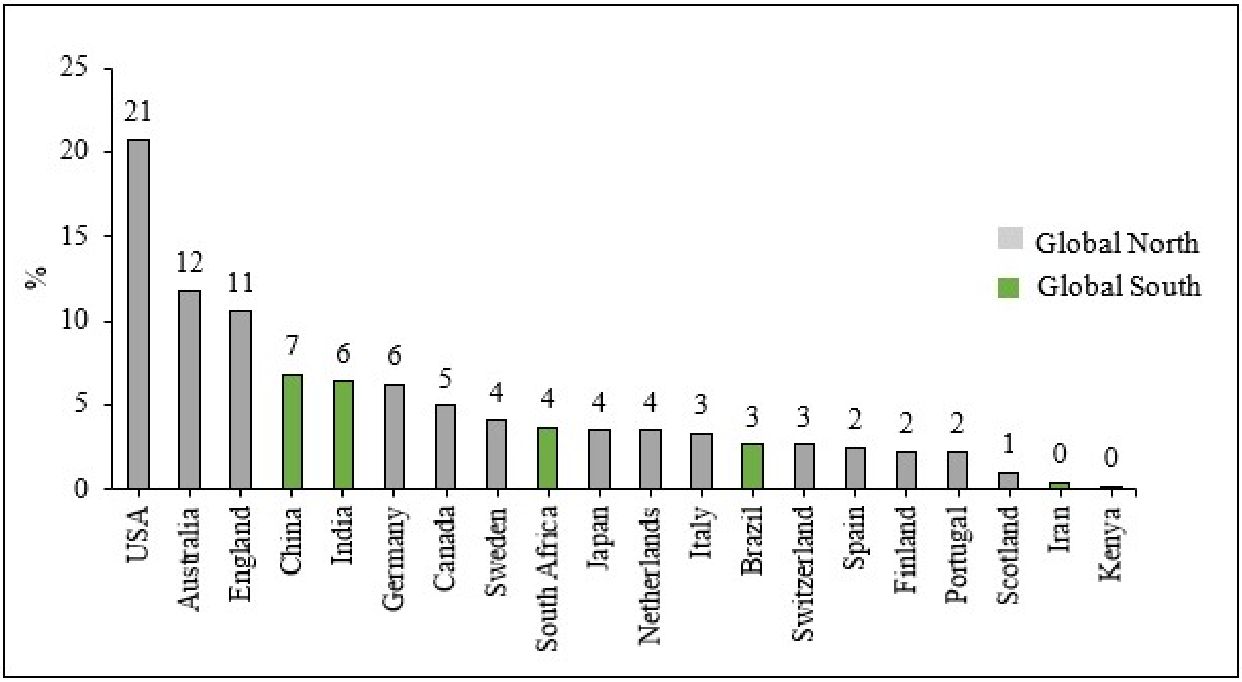

Figure 4.1: Geographic scope of literature produced between 1999-2019 (Source: Web of Science)

According to Acharya and Pathak (2019), this disparity can be attributed to the level of investment in research and development. Traditionally, research and development entail undertaking activities to develop new services or products and improve existing products or services (Kenton, 2020). A global perspective acknowledges research and development to improve people's lives by addressing various socio-economic and environmental problems. Therefore, an essential factor to consider when attempting to account for this research disparity is that developing countries invest significantly less in research and development as a part of their Gross Domestic Product (GDP) compared to developed countries.

Acharya and Pathak (2019) explain that developing countries invest poorly in research for many reasons, mainly due to the political conflicts and severe humanitarian crises experienced by these countries that require funding. Many developing nations lead advanced research in a single field which often discourages researchers from other fields of interest. According to Szomszor (2019), the Institute for Scientific Information at the Web of Science Group examined data from 10 300 unique documents in the Web of Science index and found that Nigeria produces the most research on poverty and inequality and that Tanzania contributes 39.8% of research on mother and child morbidity and mortality. However this does not seem to translate into action as Akinyemi et al., (2019) explains that over the past 10 years Nigeria's economy grew on the average by above 6% while in the same period there was an increase in inequality and poverty. While the Institute for Scientific Information study concluded that global research is evolving to address poverty, reduce inequality and the effects of climate change, this study finds that the proportion of the research undertaken is not in the context of household SET use.

Another reason that may account for the disparity in the number of publications being produced is that academics receive more funding and facilities in developed countries. Research activities in developing nations are neglected due to a lack of facilities, infrastructure, and investment, which can be found in developed countries. Developing countries also rely heavily on international funding and networks to get published, sometimes with a stipulation on research foci. This diverts academics from researching new developments or gaps in knowledge that exist within their own countries. In addition, the lack of research into the impacts of SETs on rural households in the Global South is that developed countries have been supporting the uptake and development of solar power for a significant amount of time while developing countries are still having to catch up (Ahuja and Tatsutani, 2009). Again, it is the lack of investment but because of the risk of developing countries where government policies and regulations are less stable. The high risk means higher costs of financing the initial investment, which hinders the adoption of solar technologies in these countries and the potential for impact research.

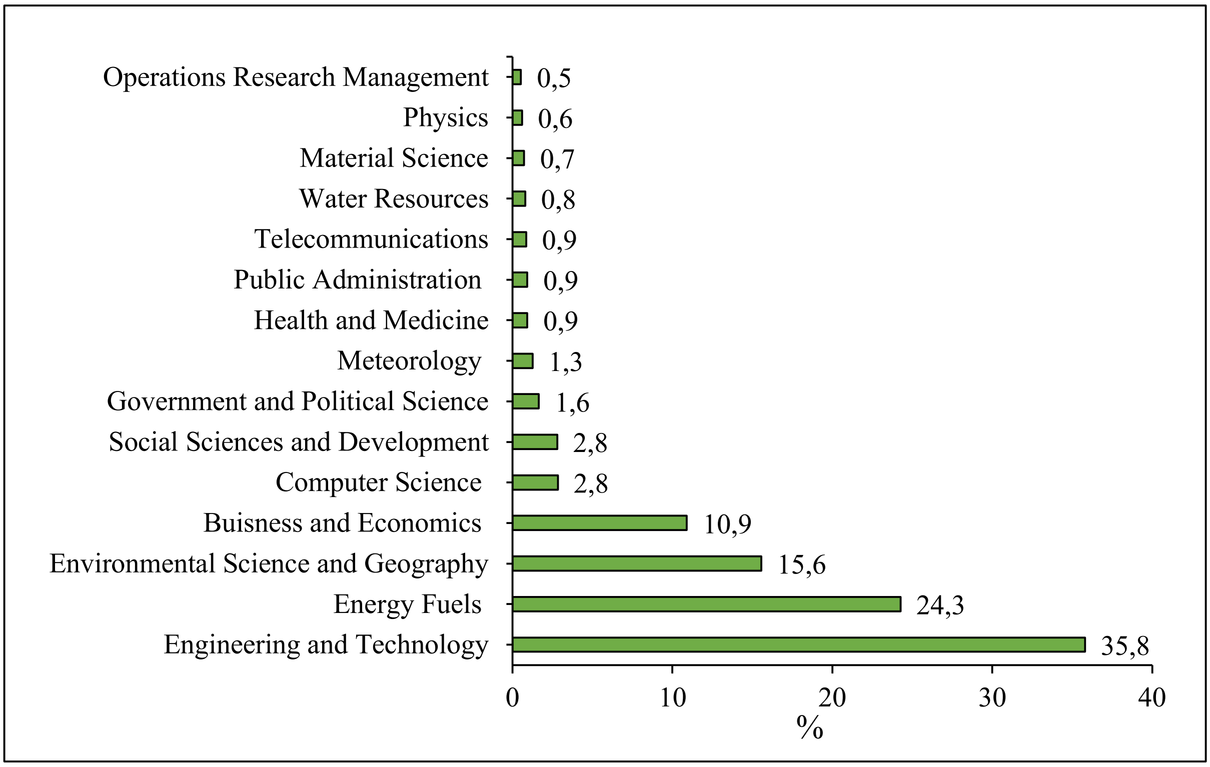

Figure 4.2: Fields of published research between 1999-2019 (Source: WorldCat and Web of Science)

Using the broad classifications of the literature according to the area of research provided by Web of Science and WorldCat, most records were from the Engineering and Technology (35.8%) category. Engineering is very closely linked to technology. While technological innovations have contributed towards the growth and prosperity of society, engineering has been the catalytic force behind it. In the case of SETs, the continuous work of engineers and technologists have contributed towards the development of various types of SETs that harness the sun's energy in varying amounts using a multitude of materials and components that have resulted in the gradual decrease in their price and increased efficacy in providing electric energy on a different scale. When combined, it is important to note that Engineering and Technology and Energy Fuel contributed over 50% of the literature found on these databases. This was followed by substantial contributions in Environmental Science and Geography (15.6%) and Business and Economics (9.4%).

This result indicates that literature accounts for social, financial, and environmental aspects of solar technologies. In total, 21 categories were identified, indicating that the research on the impacts of SETs on rural households is transdisciplinary. However, the percentage of literature produced given the temporal range from social sciences and development studies is severely lacking. This is of concern given that basic services to rural households have been widely linked to social upliftment and development in rural communities. According to Archibald et al. (2018), transdisciplinary research influences knowledge translation therefore, more research across the various disciplines or categories will contribute towards developing a shared understanding of the impact SETs have on rural households in developing countries.

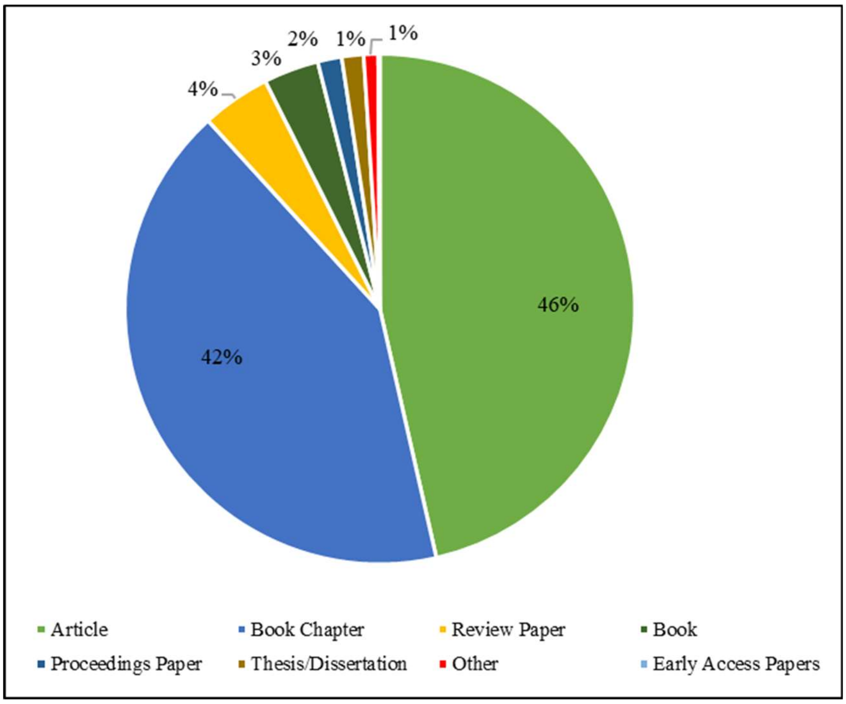

Figure 4.3: Sources of literature produced between 1999-2019 (Source: WorldCat and Web of Science)

As shown in Figure 4.3, the main sources were peer-reviewed journal articles (46%), from book chapters (42%) and review papers (4%), each differing in length and depth of detail. Guerin (2014) explains that book chapters allow more freedom to express more prominent viewpoints and approaches, while writing for peer-reviewed journals may be more concise. While both sources have their merits, it is argued that peer-reviewed journals are more accessible on databases such as Google Scholar and reader-friendly as it summarizes the principal elements and findings reducing the time needed to get the information required. The limited presence of reports and review papers is of concern since they provide a collective understanding. For example, reports from the IEA, UN and WHO may offer critical country-level comparisons, which can serve as important references or guidelines for countries aiming to transition to RETs or SETs. This is especially important for developing countries that have to be strategic with limited resources. Such reports may offer a wealth of information, lessons and even how-to scenarios and at sufficient depth.

4.2.2 Results of the systematic review and critical analysis of chosen literature

The systematic review process resulted in 56 publications included within this analysis (Table 4.1 and continued in Appendix A). According to Aksnes et al. (2019), the number of articles and citations in a category measures productivity and scientific impact. At the time of review, the publication by Chakrabati (2002) had the highest number of citations (297) while, Biermann et al. (1999), Gustavsson and Ellegard (2004), Wentzel and Pouris (2007), Adkins et al. (2010) and Grimm et al. (2016) were cited over 100 times each. The trend evident in the citation list indicates that articles published between 1999 and 2016 were cited more times than those published between 2017 and 2019. Articles tend to start receiving citations a year after publication. Smith (1981) and Kamat (2018) state that citations can also be used as a quality indicator, however, some concerns over self-citations critique these assertions.

From Table 4.1 and Appendix A, it can be seen that 38 of the reviewed publications have more than 10 citations each. According to Beaulieu (2015), publications with 10 or more citations are considered in the top 24% of the most cited work worldwide. Over time these publications will continue to engage more researchers to contribute to the growth of the discipline. Kamat (2013) asserts that low citations could also be attributed to the research theme not being mainstream and warns that good research may slip through the search owing to the volume of published papers in that specific discipline. Therefore, with an average of 45 citations per publication,, the reviewed publications hold significance in understanding the impacts of SETs on rural households in the Global South. However, the report done by Pinchot et al. (2013) received no citations according to Google Scholar. This can be attributed to several factors such as quality of paper; novelty and interest of subject; characteristics of fields and study topics, methodology or document type (Tahamtan et al. 2016). This reiterates the argument that peer-reviewed articles are preferred over reports as they are more accessible and reader-friendly.

Table 4.1: Summary of selected reviewed literature (N=56).

Year	Author(s)	Title	Times Cited	Study Location	Type of SET	Type of Unit	Type of Analysis	Type of Approach
1999	Biermann et al.	Solar cooker acceptance in South Africa: results of a comparative field-test	77	South Africa	Solar Cooker	Modular	Technical Socio-Economic	Mixed
2001	Wamukonya and Davis	Socio-economic impacts of rural electrification in Namibia: comparisons between grid, solar and unelectrified households	132	Namibia	Solar PV system	System	Socio-Economic	Mixed
2002	Chakrabarti	Rural electrification programme with solar energy in remote region–a case study in an island	297	India	Solar PV system	System	Socio-Economic Environmental	Mixed
2004	Ellegard et al.	Rural people pay for solar: experiences from the Zambia PV-ESCO project	91	Zambia	Solar PV system	System	Techno-Socio-Economic	Qualitative
2004	Gustavsson and Ellegard	The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia	125	Zambia	Solar PV system	System	Techno-Socio-Economic	Mixed
2005	Wijayatunga and Attalage	Socio-economic impact of solar home systems in rural Sri-Lanka: A case-study	57	Sri-Lanka	Solar PV system	System	Socio-Economic Environmental	Mixed
2006	Bikam and Mulaudzi	Solar energy trial in Folovhodwe South Africa: Lessons for policy and decision-makers	24	South Africa	Solar PV system	System	Social	Qualitative
2006	Pohekar and Ramachandran	Utility assessment of parabolic solar cooker as a domestic cooking device in India	31	India	Solar Cooker	Modular	Enviro	Qualitative
2007	Wentzel and Pouris	The development impact of solar cookers: A review of solar cooking impact research in South Africa	138	South Africa	Solar Cooker	Modular	Technical Socio-Economic	Mixed
2008	Obeng et al.	Impact of solar photovoltaic lighting on indoor air smoke in off-grid rural Ghana. Energy for Sustainable Development	47	Ghana	Solar Lighting System	System	Socio-Economic	Mixed
2009	Mala et al.	Better or worse? The role of solar photovoltaic (PV) systems in sustainable development: Case studies of remote atoll communities in Kiribati	66	Micronesia	Solar PV system	System	Social	Mixed
2010	Obeng and Evers	Impacts of public solar PV electrification on rural micro-enterprises: The case of Ghana	59	Ghana	Solar PV system	System	Economic	Mixed
2010	Adkins et al.	Off-grid energy services for the poor: Introducing LED lighting in the Millennium Villages Project in Malawi	140	Malawi	Solar Lighting System	System	Socio-Economic	Mixed

*Mean Citation (44.6 times)

4.2.2.1 Analysis of change over time

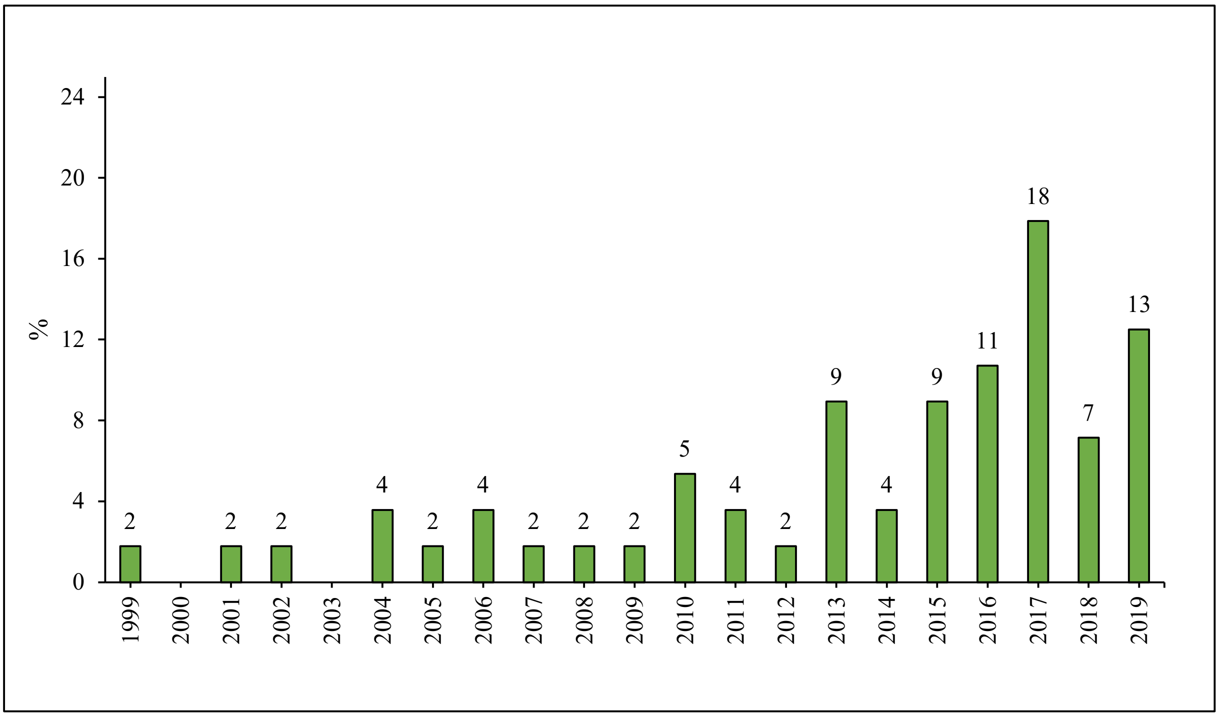

Figure 4.4: The proportion of literature reviewed between 1999 and 2019

Results revealed that the highest proportion (185) of literature reviewed was published in 2017, within the specified temporal range (Figure 4.4). A notable rapid increase in the annual proportion of published records appears from 2010. In addition, a small percentage of literature was found to be relevant between 1999 and 2009 and no publications were included in the review for 2000 and 2003. However, the general trend appears to be an increase in the proportion of published literature over time. The presence of peaks and declines may indicate events that may have influenced the research patterns within the energy field. The time series analysis (Figure 4.5) shows major global events that tabled energy in their agenda against the proportion of literature reviewed from 1999 to 2019. A timeline assessment (Figure 4.5) was carried out to reveal these aspects.

In the early years of the timeline used in this study there were some major events such as the UN Millennium Summit (2002) and the World Summit on Sustainable development (2002). The MDG's committed world leaders to eradicating poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women from the year 2000 to 2015 (Campbell, 2017). This may have generated some impetus to extend the foci of development studies to energy access, especially in relation to gender issues. This is followed by a period of limited growth. Despite the World Summit on Sustainable Development (WSSD) failing to establish a target on renewable energy in 2002, it succeeded in promoting the environmental and sustainable development needs of Africa by prioritising household energy, water and sanitation issues (von Schirnding, 2005). A spike in SET impact research focusing on rural householdss is noted from 2003, ahead of the 2005 International Conference for Renewable Energy (ICRE) event.

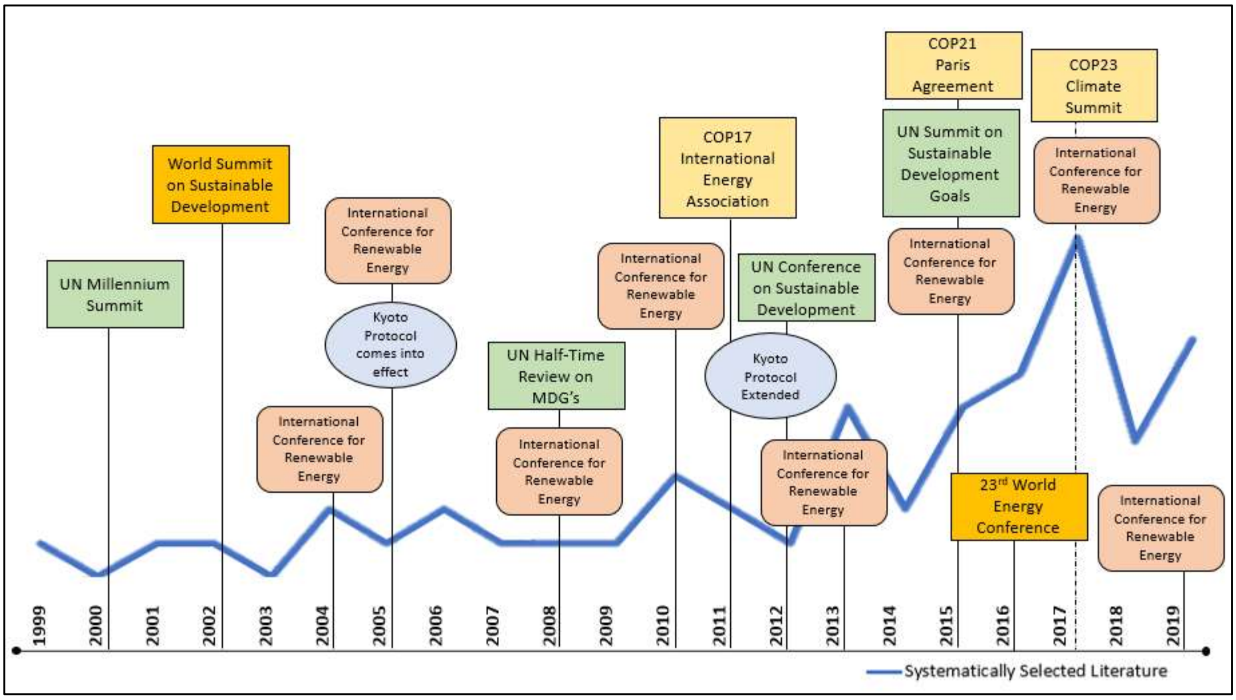

Figure 4.5: Time line analysis in relation to major events from 1999 to 2019.

Evidently, the most prominent increases in the catergory of rseserach examined in this study was noted post 2012. The significant events during this period included Congress of Parties (COP17), the UN Summit on the SDG's and the 23rd World Energy Conference. Intrestesingly, each of these events had a strong focus on energy issues, particularly in the Global South context. The succession to the SDG's in 2015 pushed a new vision that specifically identified the role of energy access with particular reference to affordiability, sustainability and reliability (SDG7). While the aims of these events varied from addressing climate change to achieving sustainable development, there was a common call for energy provision in developing countries with added emphasis on the expansion of infrastructure, technological upgrades to reduce the carbon footprint, and improving access to modern and sustainable energy services for all (Bruce et al., 2016). At the same time, it cannot be said that these events alone enabled the increase in research but may have been catalytic to this particular research agenda. Qureshi et al. (2017) attribute the inclusion of renewables and SETs in many developing countries in Asia, Africa and South America to the growing global awareness of SET potential to alleviate energy poverty, pollution, reduce carbon emission and lessen the burden on non-renewable and expensive energy sources.

From the critical evaluation over that time period, the type of SETs researched expanded across several broadly types from solar PV systems to solar cookers, solar water heaters and solar lighting systems (Figure 4.6). In addition, the results suggest that within the Global South, prior to 2008 solar cookers and PV systems dominated the domestic context. However, post 2009 there was an increased diversity in SET type. For example, the use of solar water heaters, solar lighting systems, solar passive heating and solar min-grids increased, indicating that diversification of SET types in developing countries only took place after 2010.

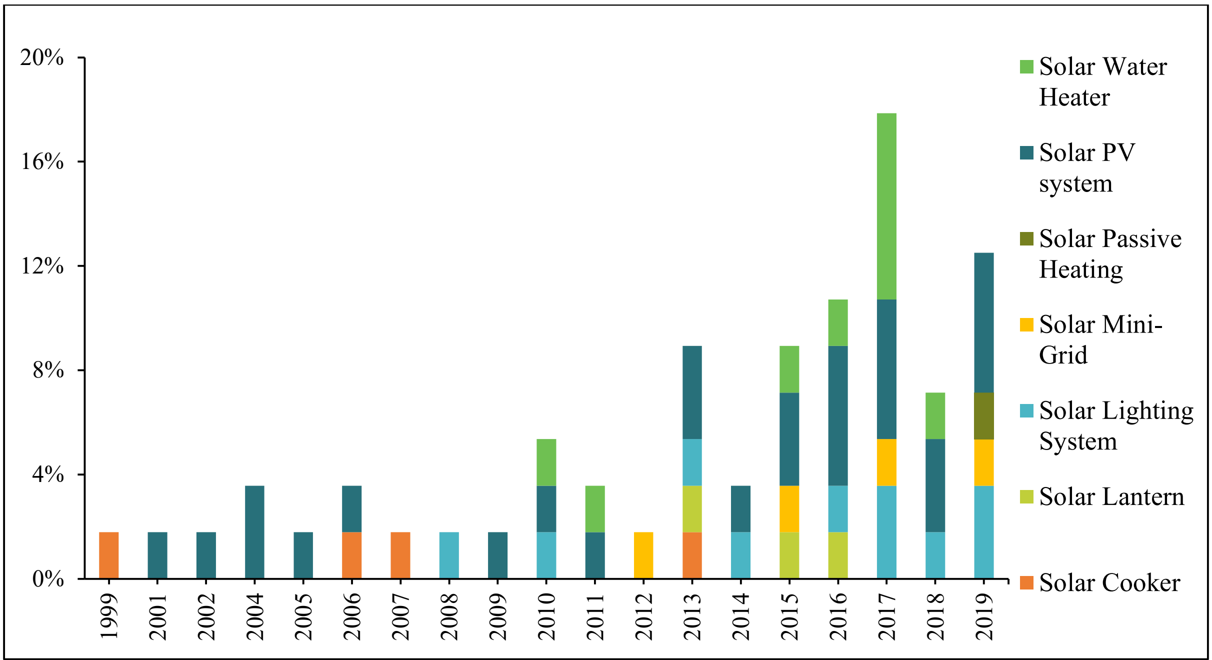

Figure 4.6: Range of SETs researched from 1999 to 2019.

Furthermore, after 2007 solar cookers were included in 2% of publications between 2008 and 2019. While a solar cooker will still make significant contribution in a rural household it is limited to clear weather, day light hours and efficacy (Wentzel and Pouris, 2007). A later study describes the weaknesses in solar cookers, available at the time of the study, to be the large size, low heating and storage capacity, resulting in longer cooking times (Zhao et al., 2018). Given the concerns around the efficacy and functionality for meeting household cooking needs, it is unsurprising that there is a decline in the presence of solar cookers in research.

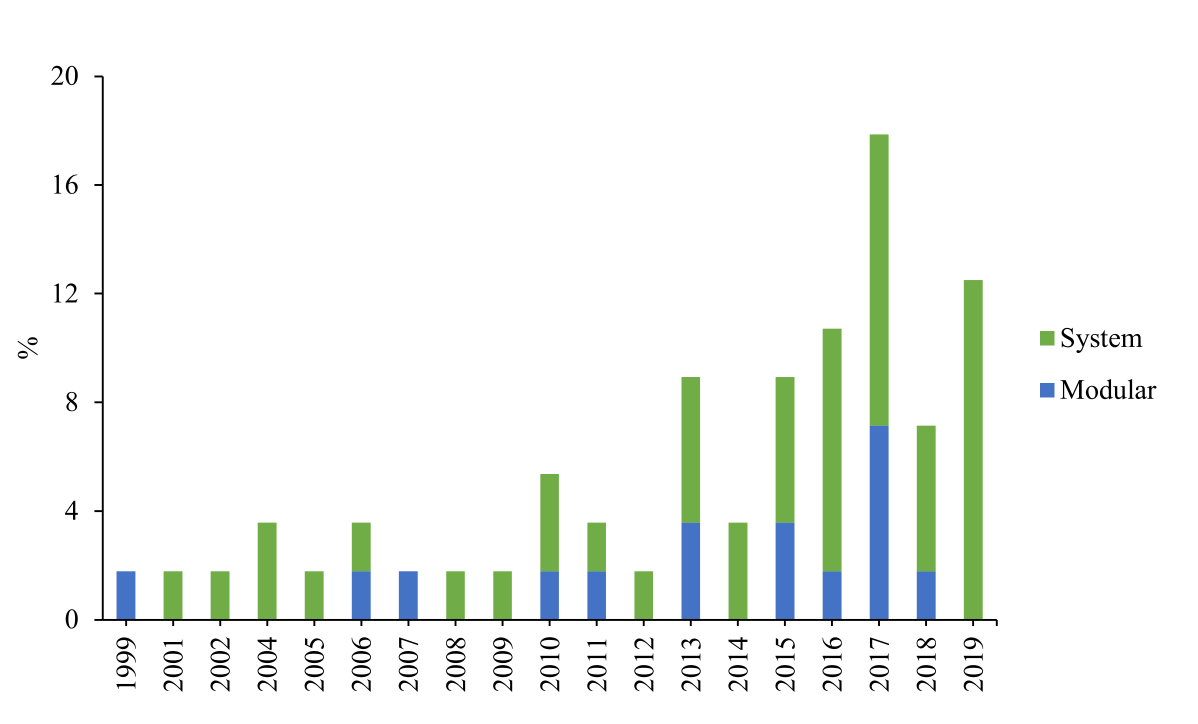

Figure 4.7: Variation in type of SETs from 1999 to 2019.

Figure 4.7 illustrates that modular SETs (SWH, solar ovens and solar lanterns) declined compared to whole system units (solar PV, solar lighting systems and solar mini-grids). Another significant result from Figure 4.6 and Figure 4.7 is that a large proportion of literature (44.6%) investigated the impacts of solar PV systems/panels on rural households from 2001 to 2019. Research shows that water heating needs account for almost 60% of household energy demand, such as South Africa (Munien, 2016). Therefore, low-cost solar water heaters provide numerous benefits to households in developing communities and are able to address both SDG 6 and 7.

Another key contribution that could account for solar PV systems, solar lighting systems, and SWH being the most researched SET's from the reviewed articles is the investment specifically towards using these technologies (Urban et al., 2016). For example, in 2017, the Chinese National Development and Reform Commission issued a Clean Space Heating Plan (2017 to 2021) for China that required all coal boilers to be replaced with solar water heaters. According to the Global Status Report (2019), several international companies experienced a gain in profits due to the increased demand for Solar Panels and SWH in Africa, which could account for the dominance of these technologies. Nieuwenhout et al. (2001) predict that one out of every 100 newly connected households in developing countries will receive electricity generated from solar power. In addition to the figures represented in the Global Status Report (2019) that showed SETs represented about 6% of new electricity connections worldwide between 2012 and 2016. Although the research undertaken maintains a focus on determining the impacts of SWH, solar PV and solar lighting systems, the adoption of these SETs in developing countries are likely to increase due to continuous technological improvements to make existing SET's more efficient and less expensive.

The results above are supported by the Global Status Report (2019), which states that India has been ranked third globally for new installations of solar PV systems and solar water heating capacity, while Brazil has been ranked fourth for the net additions to solar water heating capacity. At the same time, South Africa has more than 100MW of rooftop systems installed and has ranked fourth globally for total CSP capacity (Global Status Report, 2019). It can be argued that the growing focus on securing diverse energy services may have influenced the selection of SETs targeted for the developing context. For example, modular units such as solar laterns provide access to lighting services only, whereas solar PV panels can service multiple household energy needs.

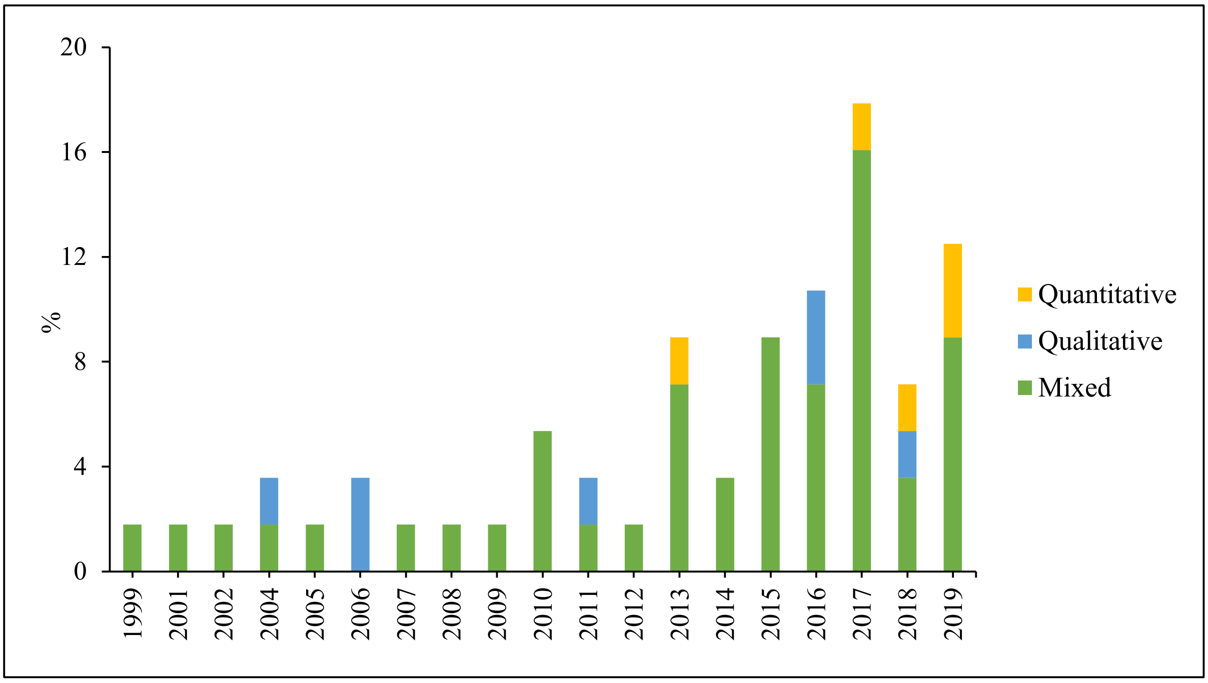

Figure 4.8: Type of approaches characterising research from 1999 to 2019.

The results from figure 4.8 show that over time the proportion (78%) of research used mixed-method approaches when investigating the impacts of SETs on rural households in the Global

South. Furthermore, the proportion of mixed-method approaches being used has increased over time (Figure 4.8). At the same time, there was a higher proportion (12.5%) of qualitative methods used than that of quantitative methods (9%). The increasing dominance of mixed-method research is encouraging since quantitve and qualitative studies alone may not capture the multi-dimensionality of energy poverty within the developing context. These results are examined in conjunction with the results depicted in Figure 4.9, which shows the types of data collection tools used in the selected studies.

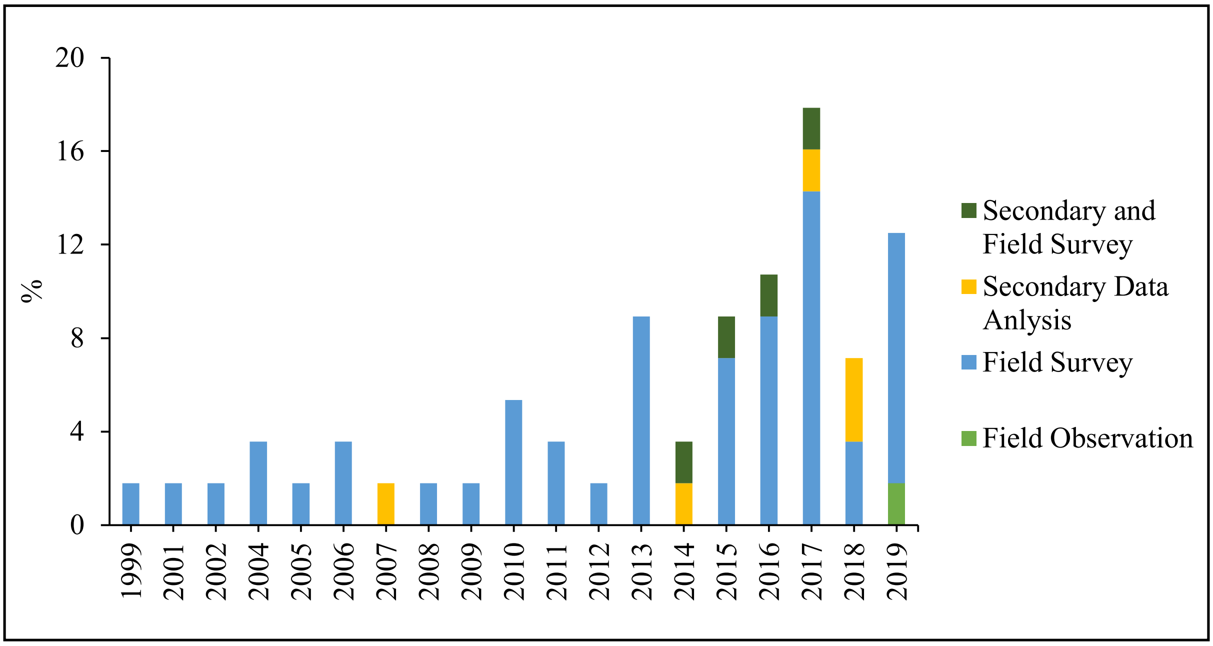

Figure 4.9: Types of data collection methods in literature from 1999 to 2019.

Approximately 82% of the reviewed publications from 1999 to 2019 used the field survey method to determine the impact of SETs on rural households. This result was earlier documented by McCusker et al. (2015) state that field surveys were one of the most frequently utilised primary data collection methods as it allows for researchers to better monitor and evaluates the impacts experienced by respondents. Similarly, Venkatesh et al. (2013) highlight that surveys and interviews are the most widely used data collection methods for quantitative and qualitative studies. Surveys are widely used in research impact assessment since it contributes to knowledge production and capacity building; and has the potential to inform policy and practice (Solans-Domènech et al., 2019). According to Krosnick et al. (2012), this is due to surveys allowing for human interaction that receive higher response rates and improve data quality and enable a deeper insight into respondent behaviour, experiences, needs, and preferences.

In the case of the reviewed articles, the surveys were used to establish, amongst others, the socio-demographic profiles, household energy profiles, perceptions and attitudes towards the SETs installed in the household and experiences before and/or after installation of the SET. Lemaire (2018) had similar results after conducting a review on impacts of solar home systems and solar lanterns, linked the increased percentage of surveys undertaken to the expansion of the off-grid solar market. As solar systems are becoming more mainstream, the large percentage of surveys over time reflects the increasing interest in the impacts of this technology by funders and private stakeholders.

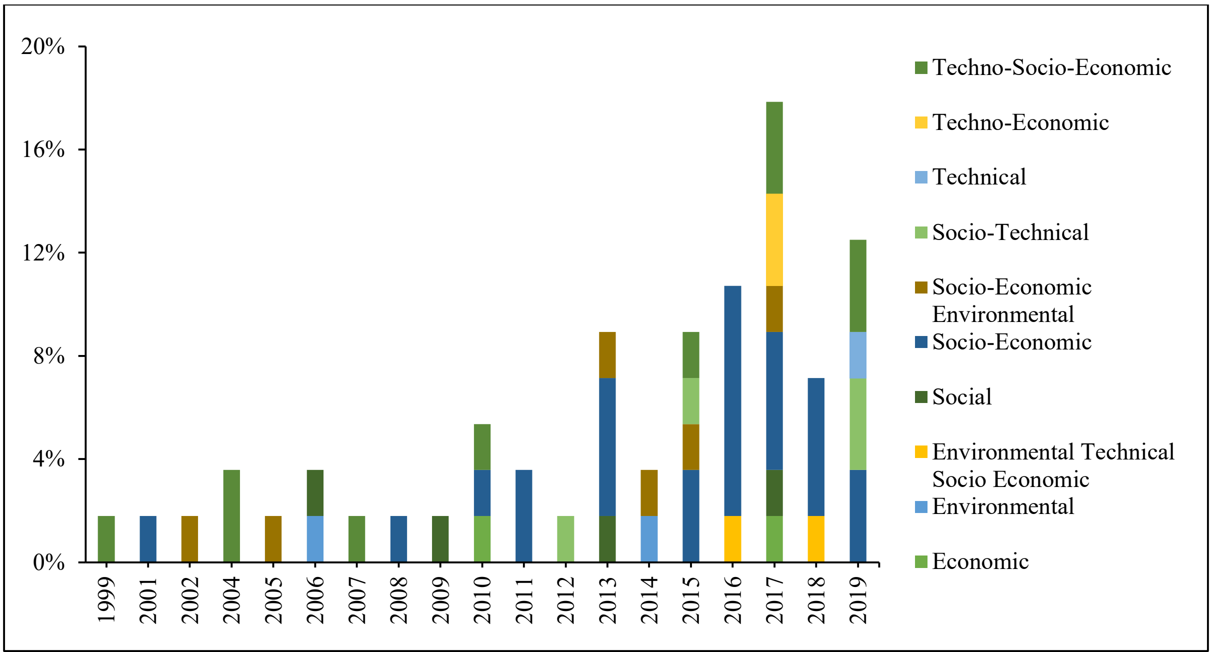

Figure 4.10: The type of analyses used in research from 1999 to 2019.

From the review literature, eight different types of analyses were identified. The type of analyses were established according to the focus of the study i.e. the device , the environment or the household, to determine the impact of SETs. As seen in Figure 4.10, the majority (41%) of reviewed publications solely focused on the socio-economic impacts of SETs. Close to 18% of publications examined technical and socio-economic impacts. Smaller proportions reflected on socio-economic and environmental impacts (11%), and socio-technical analyses (7%). The analyses of impacts have diversified over time, although there is a focus on the use of socio-economic analyses as the primary analysis or feature in a broad analysis used in a reviewed publication (figure 4.10). The analysis of technical impacts was the least used, accounting for 2% of the reviewed literature, and only appeared in 2010. Similarly, environmental technical socio-economic analyses, which were more holistic in their approach, appeared more frequently after 2010.

From the reviewed publications, various analyses and methods were used to determine the impacts of SETs on rural households in the Global South. Throughout this review, it was evident that much of the publications that sought to investigate the impacts of SET's had a consistent focus on socio-economic analyses. According to Maccabe et al. (2018), the focus of literature may be narrowed due to the field's relative novelty and depends on the shift in the availability and range of RETs available to households. Socio-economic impact assessments were initially structured to display the advantages and disadvantages experienced by society as a whole or various sectors like rural communities. In addition, Hjortsberg (2019) described socio-economic impact analyses as the most complete and scientifically robust method that contributes extensively to research that could account for it being undertaken in most of the reviewed articles in this study.

Conversely, those analyses in the reviewed publications fail to acknowledge social impacts alone were used less. The World Bank (2015) reveals that global research is progressively redirected towards addressing poverty, reducing inequality, and tackling climate change. The influence of the MDG's could account for the initial focus on socio-economic impacts, which subsequently broadened upon the introduction of the SDGs. The SDG's represent one of the most significant influences on global research to date by encouraging integrated, evidence-based assessments of targets and indicators. The recognition that progress towards one target is also linked to others and inadvertently requires science and research to include the economic, social, technological and environmental dimensions to achieve a holistic view of the impacts (Allen et al., 2018).

The systematic review revealed that the geographic scope of study locations varied across 24 countries (Figure 4.11). A country-level examination revealed that experiences from India accounted for 18% of the reviewed publications, followed by South Africa (14%), Bangladesh (13%) and Brazil- (7%). This result indicates the increasing range of Global South countries across which the impacts of SET's have been researched over time. In addition, the result may reflect which countries have introduced SET installations or have active projects that are facilitating the rollout of SETs for rural development.

4.2.2.2 *Geographic distribution of study location*

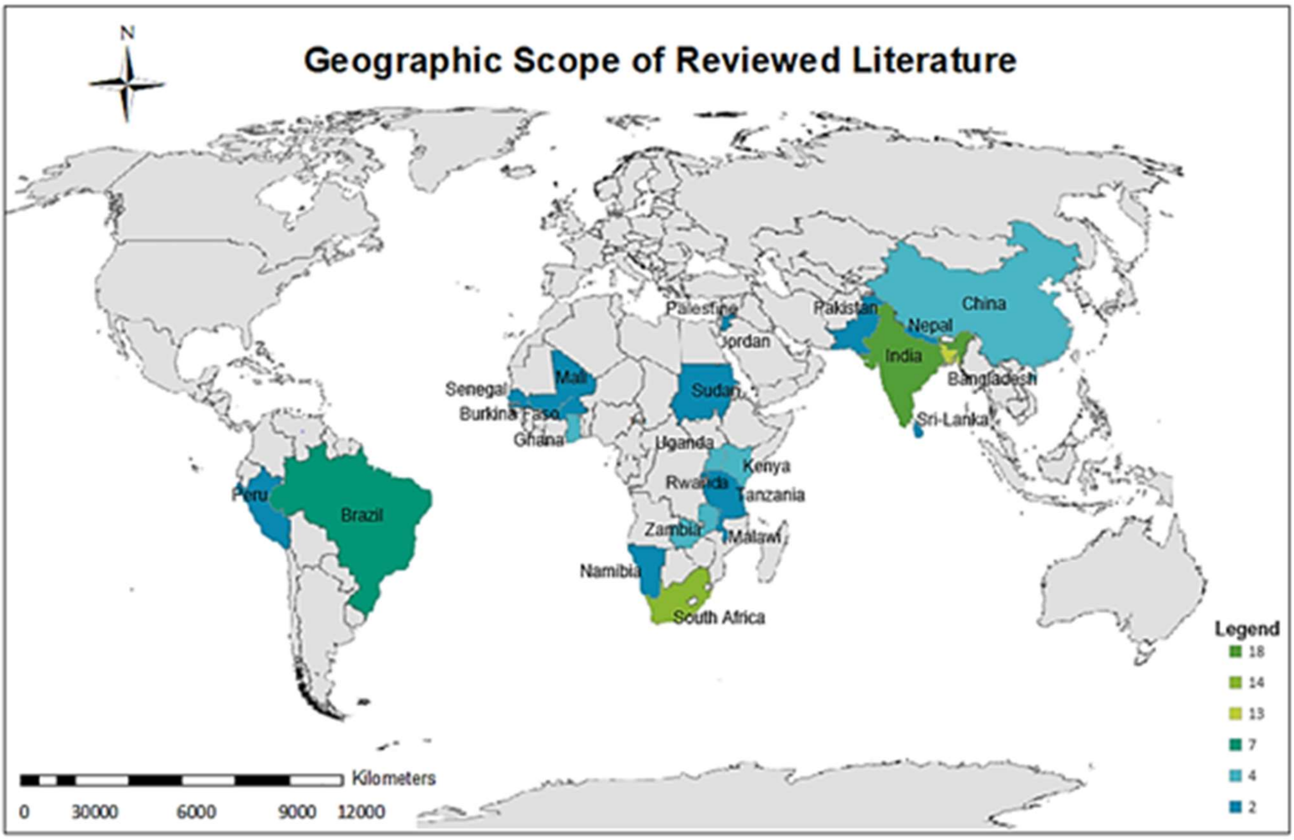

Figure 4.11: Geographic scope of case studies used in the systematic review (Author, 2020)

The majority of the publications were based on case studies conducted in BRICS countries to which this result supports the general geographic scope of literature produced between 1999-2019, which shows China, India, South Africa, and Brazil appear in the top 20 countries globally to be producing research related to the subject matter (Figure 4.11). It should be noted that 26% of studies were conducted in countries on the African continent; each was represented by 2% of the reviewed publications except for South Africa. However, based on the timeline in Table 4.1, the diversification of SETs to these African countries can be seen to have taken place after 2010 as it was previously only South Africa, Zambia and Ghana that appeared in research between 1999 and 2009. This could indicate the development of renewable energy markets taking place within Africa and that there is a push towards the use of renewables in these countries. According to Schwerhoff and Mouhamadou (2020), the prices for renewable energy have fallen substantially in the past few years, especially for solar power, whose cost decreased 77% between 2010 and 2018, which may have been a contributing factor for African countries to partake in the provision of SETs for rural households.

Essentially this result shows 56 studies were published across 24 developing countries in 20 years. This may indicate that rural development through energy provision occurs across an increasing number of developing countries. However, of concern is that the levels of progress made by certain developing countries in the roll-out of SETs are not matched by the number of published research within these sites. An example of this is that Bangladesh focused on 13% of the literature produced despite having one of the world's largest domestic solar energy programmes, which aims to provide electricity to more than 4 million rural and low-income households, roughly one-eighth of the country's population (The World Economic Forum, 2020). At present, the programme has introduced 1,000 solar irrigation pumps and 13 solar mini-grids towards rural development (World Economic Forum, 2020). Therefore, researching the impacts of SET's in Bangladesh holds enormous potential in informing other developing countries on successfully implementing similar programmes.

4.2.3 Meta-analysis of findings generated from the established framework

Table 4.2: Background of households studied in reviewed literature (N=56)

Household Demographics	Mean household size	5.9
	Proportion female respondents	37.6%
	Proportion Male Respondents	62,3%
	Main Occupation	85.7% of households engage in farming
	Level of Education	64.3% of households had 1 to 7 years of schooling.
Household Energy Profile (Before Installation)	Main Energy Need	49% of households need SETs to improve energy services
	Cooking Source	57% reported kuelwood as the main source for cooking
	Lighting Source	73% reported kerosene as the main source for lighting
	Heating Source	22% reported kerosene as the main source for heating

The purpose of the results shown in Table 4.3 is to understand the profiles of households that participated in the reviewed studies. On average, the households surveyed had 5.6 members, with more males (62.3%) than females (37.6%). Furthermore, 64.3% of literature interviewed households with an average of 1 to 7 years of schooling. In addition, 85.7% of literature reported on households that indicated the predominant occupation is farming. Of importance is that the majority (49%) of the reviewed studies indicated the households main need for using SETs is to improve the energy services they were previously receiving. Before installing their

SET, the households in these studies previously used fuelwood for cooking and kerosene for lighting and heating.

These results are a consolidation of research undertaken to determine the impacts of SETs, however, it also provides the details of rural households in the developing context. This is significant as explained by Munien (2016), who states that accurate data profiling of households, their energy use and demographics is necessary for understanding the changes experienced when transitioning to more sustainable energy sources as it provides context when it comes to establishing implementation strategies and of what technology might have a positive impact. It must be noted that other demographic information was recorded by several studies, such as household income, average age and number of children, however, due to the inconsistency of reporting from the reviewed studies and varying responses, the results could not be calculated.

Table 4.3 Classification of indicators used to measure impact.

Indicators	% Literature (N=56)	Qualitative/ Quantitative	Direct/ Indirect	Indicator Type	Years
Household Economy	100	Quantitative	Direct	Financial	1999,2001,2002, 2004, 2005, 2006,2008 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Activities Engaged due to Access to Energy Services	80	Qualitative	Indirect	Human	1999, 2001, 2002, 2004, 2006, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Installation Period	68	Quantitative	Indirect	Physical	1999, 2001, 2002, 2004, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Access to Lighting Services	63	Quantitative	Indirect	Physical	2004, 2010, 2011,2012,2013, 2014, 2015,2016, 2017,2018, 2019
Education	63	Qualitative	Direct	Human	2001,2002, 2004, 2005, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Energy Consumption	55	Quantitative	Indirect	Human	1999, 2002, 2004, 2005, 2007, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Operation and Maintenance Services	55	Qualitative	Indirect	Physical	1999, 2001, 2004, 2005, 2006, 2008, 2009, 2010, 2012, 2013, 2015, 2017, 2018, 2019
Energy Expenditure	54	Quantitative	Indirect	Financial	2001, 2002, 2004, 2005, 2006, 2008, 2010, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Health Risk	54	Qualitative	Direct	Human	1999, 2002, 2006, 2008, 2011, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Income Generating Activities and Productivity	54	Quantitative	Direct	Financial	2001, 2002, 2004, 2005, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Status of Device	45	Qualitative	Indirect	Physical	2004, 2008, 2009, 2010, 2011, 2013, 2015, 2016, 2017, 2018, 2019
Time	41	Quantitative	Indirect	Human	1999, 2001, 2002, 2004, 2006, 2007, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Solar Device Size	36	Quantitative	Indirect	Physical	2001, 2002, 2004, 2005, 2008, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019

Table 4.3: Continued

Indicators	**%Literature**	**Qualitative/ Quantitative**	**Direct/ Indirect**	**Indicator Type**	**Years**
Attitudes, Perception and Experiences of Solar Device	32	Qualitative	Indirect	Physical	1999, 2001, 2002,2004, 2005, 2008,2012,2013,2015, 2016, 2017, 2018, 2019
Gender Impacts	32	Qualitative	Indirect	Social	1999, 2002, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Quality of Life: Poverty and Vulnerability	32	Qualitative	Direct	Human	2001, 2005, 2007, 2009, 2011, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Environmental Impact	30	Quantitative	Direct	Natural	1999, 2005, 2006, 2013, 2014, 2015, 2017, 2018, 2019
Access to Water Heating Services	27	Quantitative	Indirect	Human	2010, 2015, 2016, 2018,2019
Quality of Lighting Services	27	Quantitative	Indirect	Physical	2002, 2004, 2011, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Air Quality	25	Quantitative	Indirect	Natural	2008, 2010, 2011, 2013, 2016, 2017, 2018, 2019
Communication	21	Qualitative	Indirect	Physical	2002, 2012, 2013, 2015, 2016, 2018, 2019
Safety and Security	21	Qualitative	Indirect	Human	2004, 2006, 2013, 2015, 2016, 2017, 2018, 2019
User Knowledge of Operation and Maintenance	21	Qualitative	Indirect	Physical	2004, 2007, 2011, 2013, 2014, 2015, 2016, 2017, 2019
Access to Information	20	Qualitative	Indirect	Human	2013, 2014, 2015, 2016, 2017, 2018
Social Behaviour and Interaction	18	Qualitative	Direct	Social	2002, 2004, 2011, 2014, 2015, 2016, 2018, 2019
Food Security	11	Qualitative	Direct	Human	2001, 2013, 2014, 2015, 2018
Environmental Awareness and Behaviour	5	Qualitative	Indirect	Natural	2005, 2014, 2016

***n=27:** Financial (11%) Human (37%) Natural (11) Physical (33%) Social (8%) *Qualitative (56%) Quantitative (44%) *****Direct (30%) Indirect (70%)

4.2.3.1 Classification of impact indicators

The classification of the indicators identified from the impacts recorded in the reviewed literature is shown in Table 4.3. Following the thematic recoding of 610 impacts, 27 indicators were identified and classified as quantitative or qualitative measures. An indicator was further classified as direct if the use of the SET impacted a livelihood capital base or classified indirect if the SET impacted another factor that subsequently impacted the livelihoods. Lastly, the impacted capital base, either directly or indirectly, determined the classification of the indicator as human, social, natural, physical or financial. This classification is in keeping with the UNDG's definition of impact and the SLA framework.

From the evaluation of indicators used (Table 4.3), it was established that 100% of the publications looked at impacts related to the household economy. The household economy indicator was the only indicator from 1999 to 2019, except for 2000 and 2003, which showed no published literature. The basic understanding of this indicator was to determine the impact of SETs on the household movement of money or financial assets. This indicator was a quantitative measure of the impact of SETs on household savings, income, and payback period. The proportion of studies reporting on the impacts of SET's on the household economy may indicate household financial assets being more vulnerable to the introduction of technologies and, therefore, will reflect the impacts of SETs experienced by rural households. To this effect, it may also be an indication that when compared to other indicators, it is easier to investigate the household economy.

A significant result is that while one indicator may have been used in many of the studies and across the temporal range, no studies used all the identified indicators. Only the first 10 indicators in the table (household economy, activities engaged due to access to energy services, access to lighting services, education, energy consumption, operation and maintenance services, energy expenditure, health risk and operating period, income-generating activities and productivity) appeared in more than 50% of literature in different years across the temporal period. This indicates that there were indicators that have become common to use when investigating the impacts of SETs. This result implies that the resultant impacts regarding the common indicators may be comparable across studies and over time. The least used indicator was environmental awareness and behaviour that appears in only 5% of literature, which is of concern given that the households are using green technologies to address the dual challenge of ensuring energy provision and reducing the impact of fossil fuel-based energy sources. This may indicate that researchers investigating the impacts of SET's on rural households overlook the impacts of SET's on the natural asset bases affecting rural livelihoods.

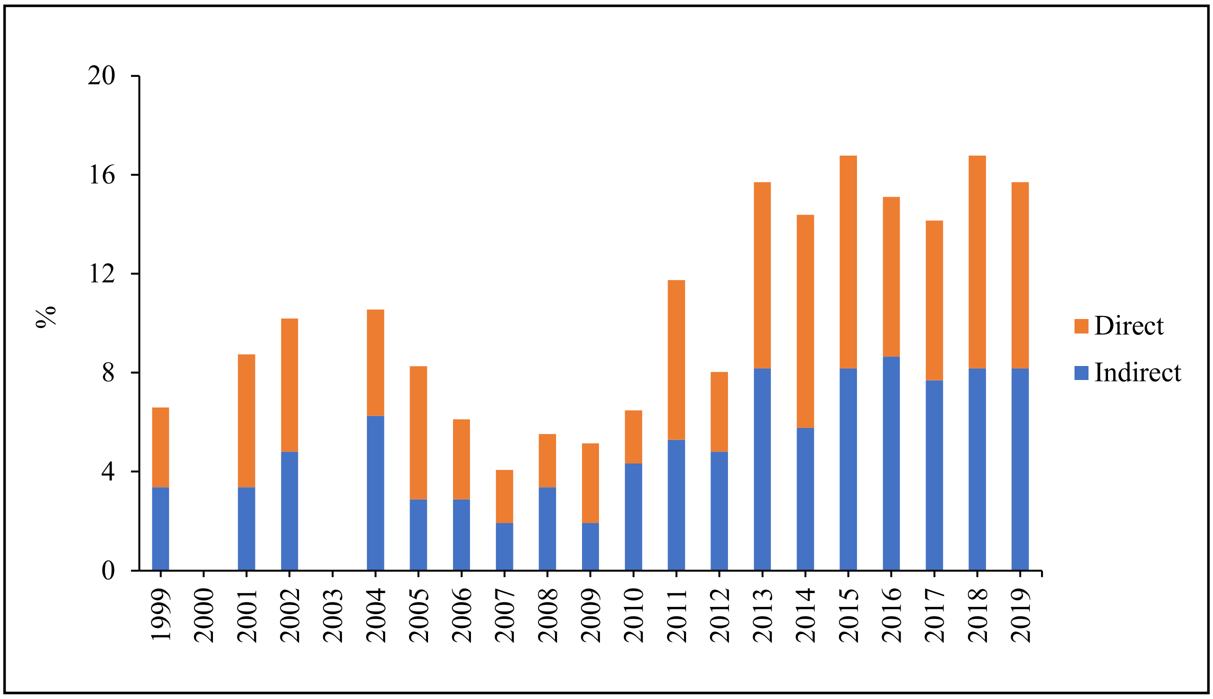

Figure 4.12: The proportion of direct and indirect indicators used from 1999 to 2019.

From the previous section of results, it was seen that the type of analyses conducted and the data collection methods showed some variance, but sources of variance can also be seen in the types of indicators used. This was apparent in the difference between direct and indirect indicators used in the reviewed articles. Table 4.3 shows that 30 % of indicators measured direct impacts while 70% measured indirect impacts. Despite the proportion of both indicators increasing from 1999 to 2019, it is evident that a higher proportion of indirect indicators were used. This result may reflect the extent to which SET's impact rural livelihoods, and to this extent, researchers are expanding their views of impact and how to quantify it. From Table 4.3 it is noticed that indirect indicators are primarily qualitative measures, therefore, it can be said that research on the impacts is accounting for the influence of the user context, i.e., lifestyles, energy behaviours and values, much like a bottom-up approach to achieving livelihood impacts.

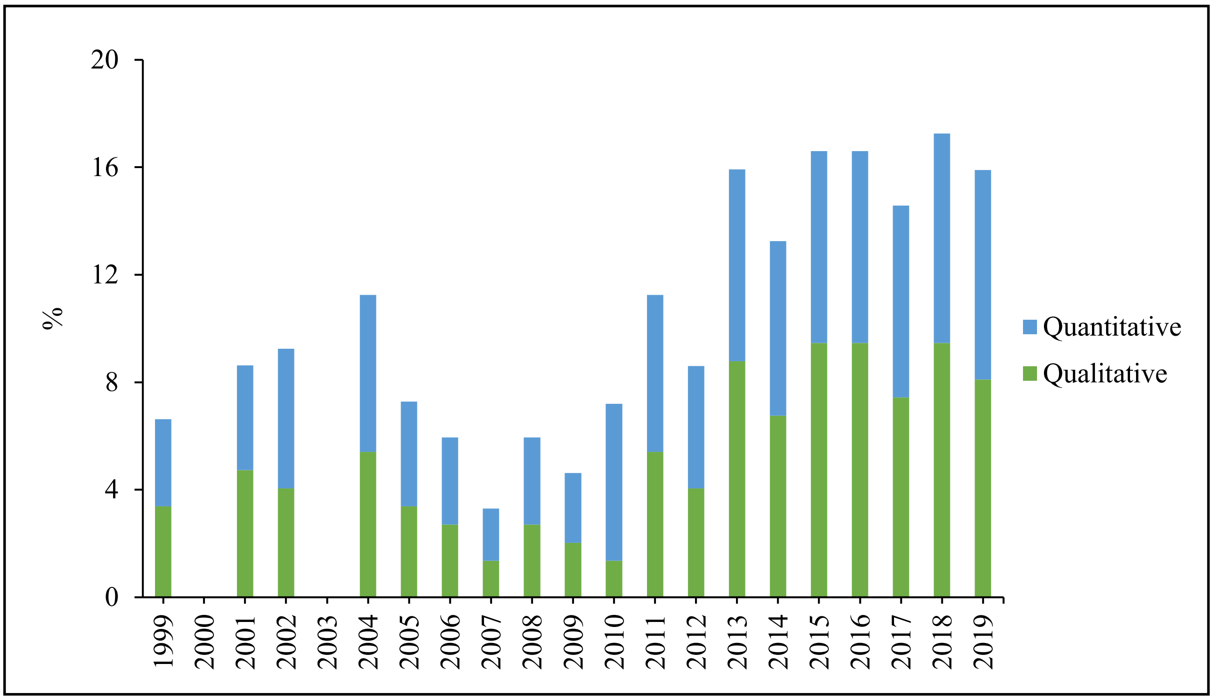

Figure 4.13: Types of indicators used to examine SET impact from 1999 to 2019.

Figure 4.13 illustrates that the proportion of qualitative and quantitative indicators used over time has increased. Typically, field surveys are the predominant method of data collection present in the reviewed articles, it is expected that qualitative indicators would be utilized more (Garbarino and Holland, 2009). While the proportion of qualitative indicators may be higher, it is important to note that from 1999 to 2010, the proportion of quantitative indicators used overtime was higher than that of qualitative. Coghlan and Brydon-Miller (2014) the presence of more quantitative indicators means that the researchers conducted complex statistical analyses to aggregate the data to generate results. Therefore, this change over time to include more qualitative indicators to determine the impacts of SETs on rural households indicates that the research accounts for more social, human, and natural impacts. Essentially the use of more qualitative indicators in determining the impact of SETs may indicate that the research focus has extended to account for the depth of impacts to livelihoods via the experiences of the households. The implications of these results may be that the research is becoming more robust.

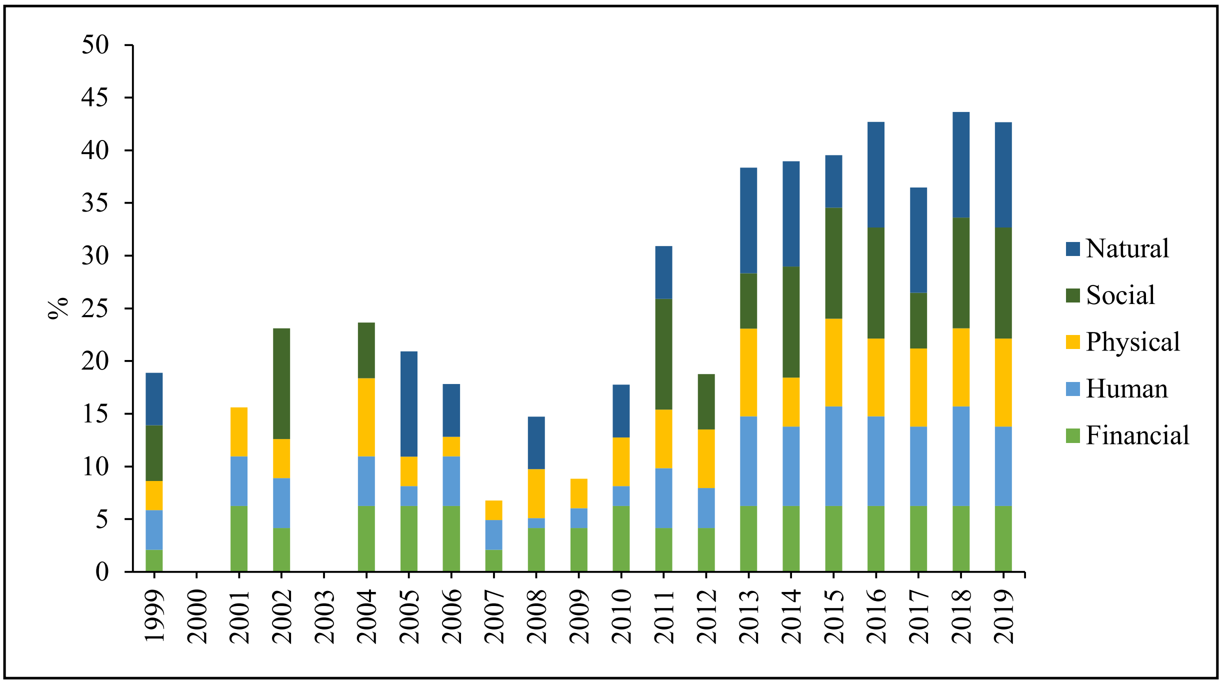

Figure 4.14: Reported Livelihood indicators used to examine SET impacts from 1999 to 2019.

From the evaluation of the classification of indicators (Table 4.3), it was found that indicators quantified the broad spectrum of livelihood assets. 37% of indicators investigated impacts towards human assets, 33% towards physical assets, 11% towards financial and natural assets and 8% were towards social. Despite more human and physical indicators being identified in the classification, there has been a noticeable mix of livelihood indicators used in the research undertaken over time. Figure 4.14 shows an increase in the diversity of livelihood impacts investigated. More importantly, from 2013 onwards there is a visible shift in the proportion of research that use these livelihood indicators to gauge impact of SETs.

These results may be an indication that there is an increased understanding that impacts of SETs are not only as a result of the performance, but also the usability, flexibility, and multi-functional capabilities in meeting rural household energy needs in terms of physical, financial, social, environmental, and human outcomes. Furthermore, this shows that the indicators used have diversified and are more inclusive of the multidimensionality of livelihood impacts. The importance of the results shown above was previously highlighted by MaCarty and Bryden (2017), where it was stated that technologies that are meant to provide energy services in such a way that they address technical, financial, environmental and social objectives and of the technologies investigated none of which successfully address all. The mean impacts according to indicator type are discussed below.

4.2.3.2 Analysis of SET impacts on rural households

The meta-anlysis of impacts recorded from the studies that reported were analysed to determine the mean impact that SET's are having on rural households. The results are discussed below in relation to the proportion of studies that reported positive , negative, increased or decreased and no affect impacts.

4.2.3.2.1 Financial capital impacts

Table 4.4: Mean financial impacts identified from the reviewed literature

Indicator	**Mean Impact**	**% Literature**
Household Economy	Increased Household Savings	91
	Increased Household Income	100
	Payback Period (≥ 5 years)	83
Income Generating Activities and Productivity	Increase Income Generating Activities	79
	Increased Productivity	67
Energy Expenditure	Decreased Kerosene Expenditure	100
	Decreased Energy Expenditure	74
	No Affect/ Decrease Fuelwood Expenditure	50/50
	Decreased Alternate Light Source Expenditure	100

The use of SET's resulted in an increase in household savings according to 91% of the reviewed studies that looked at the household economy. Mishra and Behera (2016) found that the marginal increase in household savings could be primarily attributed to reduced kerosene consumption for lighting. This study supports that claim as 100% of the reviewed studies that accounted for energy expenditure reported a decrease in Kerosene expenditure and other lighting sources. These results show a decrease in the consumption of traditional energy sources, which indicates the extent to which the SETs are meeting the energy needs of rural households.

The mean result found by this study elucidate that, in general, the impacts of SET's used for electrification have mainly been positive, especially benefits of reduced kerosene consumption, ease in studying and cooking and reduced health effects, as reported by Sharma et al. (2019). Grimm et al. (2016) observed a significant and considerable drop in kerosene expenditures by almost 70%. Similarly, this result was determined in the study by Curry et al. (2017), where 73% of the households surveyed made an average savings of 27% on their monthly electricity bills. When asked what they spent the extra money on, one interviewee stated that they were saving the money, while the majority replied that they spent the savings on food. Wlokas (2010) explains that the installation of SWHs allowed households to save money spent on other energy sources, which is now used to buy other home appliances that run on electricity that aid in making their chores more efficient time-saving.

The use of SETs increased income-generating activities and productivity according to 79% and 67% of the reviewed literature that used these indicators. Mishra and Behera (2016) reported that some of the women in their study use SHS for various economic activities such as running sewing machines and doing stitching related works at night. Sapkota et al. (2014) explain that the SETs extend the duration of lighting provided, allowing households to carry on with domestic income-generating activities like sewing further into the evening after the household chores are complete. However, it should be noted that while there were decreases in expenditures for kerosene and other sources of light, not all households experienced a decrease in energy expenditure, specifically fuelwood. Table 4.4 shows that 50% of the studies that record this impact mentioned no effect on fuelwood expenditure, while the other 50% reported a decrease. The no-effect may be attributed to the cost paid towards their solar device or the fact that their SET does not meet all their energy needs and, as a result, have to resort to fuel stacking to compensate. Fuelwoods provide a dual-energy service to rural households in that it provides both a lighting and heating source. Therefore, for a decrease in fuelwood expenditure, the SET needs to provide both of these services.

4.2.3.2.2 Human capital impacts

Table 4.5.1: Human impacts identified from the reviewed literature

Indicator	Mean Impact	% Literature
Activities due to Access to Energy Services	Increased engagement in modern activities (TV, Radio, communication)	94
	Decreased Alternate Appliance Use	56
Energy Consumption	Decreased Kerosene Consumption	100
	Electric Grid Energy Consumption	87
	Decrease Fuelwood Consumption	67
Health Risk	Decreased Health Impacts	95
	Improved Sanitation	100
Access to Information	Increase access to information TV, radio, mobiles	100

Several consumption impacts appeared over time and across the reviewed studies. From these, the impact on kerosene consumption was most common. This is unsurprising since kerosene has been used as the main source of lighting by non-electrified households and households with intermittent access to electricity, with around 43% of the rural households depend on kerosene for lighting in India (Murali et al., 2015). Mondal and Klein (2011) found that reducing kerosene usage was the main impact of SHSs. This can be seen as 95% of the literature that looked at human impacts reported decreased respiratory difficulties, eye strain and blocked noses due to smoke inhalation. Table 4.5.1 shows that all studies that used access to information as an indicator, found that SETs increased households access to information by powering sources of information such TV's, radio, mobiles which may have positive indirect impacts on the health of household. Hakiri et al. (2016) demonstrate in their study that reduced indoor air pollution and access to health information via radios, television broadcasts improve the knowledge of the respiratory illness, family planning, personal hygiene and sanitation in rural households.

Table 4.5.2: Human impacts identified from the reviewed literature (continued)

Indicator	Mean Impact	% Literature
Education	Increased Study Hours	91
	Academic Performance	100
Food Security	Increased food security	100
	Improved Cooking Services	67
Quality of Life: Poverty and Vulnerability	Increased Quality of Life by Reducing Poverty and Vulnerability	80
Time	Increased Time (saved, reallocated)	76
Safety and Security	Improved Household Safety	73

According to 76% of literature that used time-savings as an indicator recorded that using SETs increased in the time available to household members per day. The indicator time included time saved from cooking, undertaking chores, collecting fuelwood and bathing. In the study done by Curry et al. (2017), households that expressed willingness to pay for their SWH were motivated not by financial savings but by the prospect of saving time and improved efficiency. According to the study done by Gray et al. (2018), the total productive hours available to rural households are especially important after sunset as it extended their day by 1.8 hours. Based on the study by Kabir et al. (2017), for many households, the introduction of SETs extended the light hours available and facilitated in providing children with more time to study, and women no longer depended solely on sunlight to complete their household chores.

As mentioned in the motivating studies, time saved was more time to allocate to other activities such as studying. From Table 4.5.2, it can be seen that 91% of literature that looked at the impact of SETs on households through education found that study hours had increased. Lemaire (2018), who conducted a similar review, states that all but one study included in his review indicated minor positive impacts of using SHS on extended study hours. The use of SHS at home enables children to study after dusk in better conditions compared with the use of kerosene lamps, at home where children congregate in houses with solar home systems. The results shown in Table 4.5.2 indicate that the increased study time has improved children's academic performance in the household as 100% of the literature reported an increase in academic performance. Students' academic results indicated a clear improvement in academic performance with access to quality light in the evening in their homes (Mondal and Klein, 2011).

All literature examined in this systematic review reported improved cooking practices post-installation of SETs. The World Food Programme (2019) explains that food insecurity and poor nutrition result from high energy costs and energy scarcity, forcing households to exchange food rations or crop yields for fuel. Gray et al. (2018) reported that since using solar lanterns, the households prioritise their supply of nutritional foods as they indicated that the majority of their savings from kerosene on food, water, and then education. Table 4.5.2 additionally shows that 80% of literature that investigated the impact on household quality of life reported an increase in quality of life to reduce poverty and vulnerability. This result, coupled with the result discussed above, indicates that SET's are significantly impacting rural livelihoods positively by addressing energy needs and other household needs, such as increasing food security, creating the opportunity to get purified water, and improving the educational state of children in the household.

The following sections show the impacts recorded according to the proportion of studies reported against the indicators classified for this section. Therefore, the number of studies vary, and the percentage literature is not based on the total number of studies in the review.

4.2.3.2.1 Physical capital impacts

Table 4.6.1 Mean physical impacts identified from reviewed literature

Indicator	Mean Impact	% Literature
Operation and Maintenance Services	Poor Operational and Maintenance Services	60
	Provided Spares-After-sales Services	80
User Knowledge of Operation and Maintenance	Poor Knowledge of operation and maintenance	64
	Increased Community Skills Development	100
Status of Device	Functionality Status: Working	87
	Yes -Technical Problems Experienced	83
	Durability/Lifespan	13.5 Years*
Solar Device Size	Good Energy Output	67
	Good Battery Capacity and Performance Ratio	100

From the reviewed studies that investigated the impacts of SET's using the physical capital indicators in Table 6.1, it can be seen that 100% reported an increase in community skills development, increased communication and that the solar devices installed had a good battery capacity and performance ratio which were based on quantitative measures. Research reports that in 30% of the studies, SETs were installed for 1 to 2 years of which an average of 87% were recorded to be still working. Important to the impacts recorded is the number of years it has been installed at the time of the study as it gives an indication on when the impacts experienced are to be expected. The functionality status given the time installed provides insight into the quality of the device. Although, of concern is that of those reviewed studies that looked at physical impacts, 60% reported poor operation and maintenance services despite 80% recording that they were supposed to receive spares and after sales services. In addition, the household user's knowledge of operation and maintenance was reported to be poor by 64% of reviewed studies that investigated the indicator.

Table 4.6.2: Mean physical impacts identified from the reviewed literature (continued)

Indicator	Mean Impact	% Literature
Access to Lighting Services	Increased Light hours	70
	Increased Lighting Facilities (e.g., Lights /room)	88
Access to Water Heating Services	Water Temperature	-
	Increased Hot Water Supply	80
Attitudes, Perception and Experiences of Solar Device	Positive Attitudes, Perception and Experiences of Solar Device	75
Quality of Lighting Services	Increased Quality of Light	92
Communication	Increased Communication	100

Over 70% of those reviewed studies that investigated the impacts of the quality of lighting services and access to lighting services reported increased light hours, increased number of lighting facilities within the household and increased quality of lighting due to their SET. According to Pinchot et al. (2013), kerosene and other fuel-based lighting generate poor quality of light at even lower efficiency rates. Given that the recommended level of 150 lux is needed for studying and 300 lux for a general living area, the 1 lux of light generated by a kerosene wick lamp is severely insufficient. Their study compared the quality of light of the kerosene lamp to a standard solar lantern and found that the amount of light emitted from the 'D.light' represents a 466% increase from the average kerosene wick light. Furthermore, Lemaire (2018) states powerful solar lanterns can provide light for up to 12-16 hours without recharging, and a PV system can provide light in several rooms of a house for several hours.

Given the frequency with which SWH were investigated, it is of concern that the impact on water expenditure was not included in studies more often over time. In addition, this impact would provide helpful information given that some households surveyed had complained that the solar water heater had made them poorer overall, as the water bill increases were more significant than the electricity savings as a result of hot water consumption increasing during baths (Curry et al., 2017).

4.2.3.2.4 Social capital impacts

Table 4.7 Mean social impacts identified from the reviewed literature

Indicator	Mean Impact	% Literature
Social Behaviour and Interaction	Increased Social Interactions	100
Gender Impacts	Improves Women's Decision Making	8
	Improves Women ability to earn Income	8
	Improves Women Wellbeing	17
	Improves Women's Time Flexibility	17
	Improves Equity and Awareness	8
	Improves Night Studying Opportunities for Women	8

Table 4.9 shows that from the studies that looked at the impacts of SET' on the social assets of rural households found 100% of the literature reported that social interactions had increased in addition 66% reporting improved impacts on women. Social interactions increased as individuals would gather at their neighbour's or friend's households as they have a solar panel that generates enough energy to power a TV or radio (Lemaire, 2018). Because the light hours in a day per household increased, some studies stated that the social cohesion between family members increased because they spent more time together engaging in activities simultaneously, e.g., watching tv, cooking or studying together. Komatsu (2011) reported that 68% of families said neighbours often came to their homes, demonstrating that SHS benefits extended to households without energy services. Lemaire (2018) solar systems have an impact on social relations sometimes differentiated by gender. The results shown above shows that most of the studies had indeed recorded impacts on women. Gray et al. (2018) explain that time poverty in African societies affected women and girls more severely as they are burdened with many domestic and tedious tasks. Therefore, women often are unable to allocate enough time to both productive and household tasks.

While gendered issues have been mainstreamed in areas such as health and education, energy has largely been left out until recently. Murali (2015) found that one of the most significant impacts of lighting on women is that 80% shared that they find it very convenient and faster to cook under solar light than kerosene lamps. Furthermore, it was found that using an SHS reduces the time spent maintaining and refuelling kerosene lamps, a task previously undertaken by women and girls (Sapkota 2014; Kabir et al., 2017). In households with members in work and/or with school-age girls, the extra hour gained in morning/evening usually proved valuable as they could do additional reading and homework, averaging 2.5 hours per day (Mondal and Klein, 2011). As a result, they are now better placed in the family and society (Mishra and Behera, 2016). According to Lemaire (2018), the acknowledgement that women's lives are improving in these ways indicates transforming society through the provision of clean and efficient energy services from SETs. However, it must be noted that while the impacts of these social indicators were included in this study, there were several others used but only in one of the reviewed studies showing the inconsistencies present between studies that make it difficult to compare and determine the mean impacts of SETs.

4.2.3.2.4 Natural capital impacts

From Table 4.10, it can be seen that SET’s have had a significantly positive impact on the natural asset that influence rural households. This reflected in 100% of the studies that used environmental awareness and behaviour as an indicator found that households had become more environmentally conscious, increasing their inclination to protect and conserve the environment they live in and live off. The concern was that environmental awareness would inhibit the adoption of SET, given that social gatherings have increased, and the increased awareness will likely spread from one household to the other.

Table 4.8 Mean natural impacts identified from the reviewed literature

Indicator	Mean Impact	% Literature
Environmental Awareness and Behaviour	Increased Environmental Protection Resource Conservation	100
	Decreased Pollution	93
Air Quality	Improved Indoor Air Quality	67
	Increased/No Affect Indoor Air Temperature	50/50
Solar Potential	High Solar Potential	67

From the results above, it was found that 93% of the same studies reported a decrease in Pollution, with 63% recording an increase in indoor air quality. Pinchot et al. (2013) explain that fuel-based Kerosene based lighting also causes indoor air pollution through the emission of fine particulate matter. In the typical small households, rural settings with poor aeration keep the particles trapped, therefore burning a lamp for too long will lead to toxic particles. Therefore, generating energy from solar panels emits minimal pollution into the air because it uses solar energy, a much cleaner energy source. Wolkas (2011) reported that indoor air quality appeared to have improved due to the substitution of fossil fuels.

From the analysis of mean impacts, the overall impression given is that SET's positively impact the livelihoods of SETs in rural households in developing countries. However, besides financial and human impacts, there were insufficient studies that looked at the same indicators or measured them in the same way to draw definitive conclusions on the impacts on the natural, social and physical assets of rural households.

4.3 Conclusion

This chapter presented the results and discussion of the findings from the data collected from 56 reviewed publications. This chapter was divided into three main sections: the preliminary research findings from the initial database searches, the systematic review and critical analysis of chosen literature, and the meta-analysis of results reported in the reviewed literature. The preliminary findings show a significant difference in the proportion of research emanating from countries from the global north and south. The areas of research indicate that research articles on the impacts of SETs are diversifying across disciplines. The main findings show that research fluctuates according to the global energy narratives, analyses and data collection methods largely stayed the same; however, the types of SETs and geographic scope of the study locations increased. The meta-analysis and classification revealed that the most significant proportion of variance was in the type of indicators used to investigate SET impacts. However, the analysis results of mean impacts demonstrate that SET's have a largely positive impact on rural households. These aspects are discussed in detail in the next chapter, which summarises the key findings and presents concluding remarks and recommendations emanating from this study.

CHAPTER FIVE

SYNOPSIS OF RESULTS, RECOMMENDATIONS AND CONCLUDING REMARKS

5.1 Introduction

This research study set out to examine the approaches and techniques used to establish the impacts of SETs on rural households in developing countries over time to inform how the impact of these technologies is researched in the future. The following primary research questions underpin this study: how has the research (the types of analyses, methodologies, and indicators) been conducted to determine impact changed over 20 years (1999-2019), and to examine the diversity and inclusivity of indicators used to determine the SET impact on livelihoods. In terms of the latter, the SLA framework guided the understanding of livelihood components that can be used to show impact. Energy is central to sustainable development and poverty reduction, particularly at the household level, where it is linked to access to water, productivity, health, education, and gender issues. In addition, improved energy security significantly reduces household vulnerability to shocks and stressors. This chapter aims to provide a synopsis of the main findings discussed in relation to the research aims and objectives that framed this study. The recommendations of this study are presented next and followed by the concluding remarks on the overall research process.

5.2 Synopsis of results

A systematic review with elements of narrative analysis was combined to acquire information on the research being produced by Global South countries. The resultant publications were examined in detail the following information was extracted: author(s), year of publication, geographic scoping (where the study took place), type of analysis, research method, data collection tool used, socio-demographic profile of the household/respondent, information about the household energy profile before and after SET installation and any indicators that were mentioned, listed, or described. This provided robust data that allowed for the identification of trends in the research published over time. Furthermore, it provided an opportunity to determine whether the research being produced on impact is unbiased and holistic. It is imperative for the future development and implementation of SETs in rural and low-income households.

This study's main findings will be discussed thematically in relation to the overall aim and objectives described in the introductory chapter. Furthermore, this study unpacked the types of SETs investigated, the geographic scope of the publications, the inclusivity and diversity of impact indicators, and the subsequent impacts recorded. This was achieved by addressing the research questions posed in Chapter 4. This summary indicates that the overall aim and objectives guiding this study were achieved.

5.2.1 Systematic review

At the beginning of the systematic review process, it became apparent that a vast amount of research exists on the impacts of SETs. This can be understood as a reflection of the growing interest in SETs and the expansion of the industry with respect to household installations in general. However, moving through the screening process, it becomes apparent that most of the studies are not relevant, and the resultant number of studies is less than a fraction of the initial search number. This is of concern, considering impact research is integral for the growth and successful implementation of these technologies. Additionally, the preliminary results show that much of the research being done on the impacts of SETs on rural households has been produced by developed countries. However, the research disparity between the global north and south can be attributed to several reasons, the level of investment into research and development, the brain drain from developing countries, and the prioritisation of other developmental agendas that are prioritised in research. Lastly, developing countries have to catch up with developed countries supporting the uptake and development of SETs from an earlier stage. Reducing the research gap between the global north and south should be considered seriously since sustainable energy security can potentially unlock several other benefits for developing countries.

The results show that the bulk of these studies are from the Engineering and Technology, Energy Fuels, Environmental Science and Geography, and Business and Economics fields, suggesting an economic and technocentric focus. In this case of this study, the literature was likely to account for human, financial, and technological aspects of solar technologies. However, this was misleading, in much the same way as the literature that progressed through the screening of the title and abstracts did, only then to establish that they could not be included after the full-text review. The systematic review process also revealed that only one other review study was conducted in 20 years. Of concern is the lack of interest in consolidating the impacts of SETs to determine prospects for future thinking and planning.

5.2.2 Critical review of change in research between 1999-2019

This study aimed to determine how research on the impacts of SET has changed. The secondary object of this study was to establish changes over a 20-year cycle through the systematic review. The review presented findings from 56 studies from three different academic research databases (Google Scholar, Web of Science, and WorldCat) published from 1999 to 2019. The critical evaluation revealed that the research had changed over time in terms of the geographic scope of study locations, the number of publications per year, methodological approaches to examine SET impacts, and the types of indicators used to assess impacts. The critical evaluation revealed that the use of indicators varied over the years. For example, there was a migration from econometric and Technometric indicators to include aspects specifically targeting livelihood outcomes. This is promising and suggests a shift in how SET impacts are being conceptualised for the domestic sector.

The analysis of these studies revealed an increase in the proportion of research undertaken on the impacts of SET's on rural households over time, prominently reflecting the rapid increase in the proportion of literature available from 2010 onwards. The timeline assessment of international events that may have affected the global energy narrative shows the coincidental dips and surges in research. Global events that emphasised energy, such as COP17, have created the impetus for research in the field. However, the most significant was the rapid increase between 2015 and 2017 following the UN Summit on Sustainable Development Goals and COP 21, where the Paris accord on climate change was signed. These two events prioritised the need for developing countries to transition towards renewable energy, with the UN Sumit on the SDGs dedicating an entire goal towards energy provision. Therefore, the apparent increase in literature may be due to the need to provide feedback on how regional or local initiatives in developing countries are progressing or regressing against energy goals. The influence of the MDG's and the successful transition to the SDG's may contribute towards not only the disparity in research that exists between north and south but also why publications relevant to this review appeared scarcely from 1999 and more abundantly from 2015.

The citation analysis revealed that articles published between 2004 and 2016 had more citations than those published between 2017 and 2019. This follows the general trend over time, as citations for a given publication will increase. Based on the relatively high average number of citations per publication, it is likely that the research presented in these studies are likely to be of significance in understanding the impacts of SET on rural households, given that the number of publications is few. Those reviewed articles with a low number of citations can also be attributed to the research theme not being mainstream or the presentation of the research findings being difficult to comprehend. Of concern is that this comparatively small, accumulated body of research is considered a novelty on the subject matter. This is especially worrying given that the number of studies that fail to provide more holistic accounts of impacts experienced by rural households.

Over time there was a noticeable increase in the diversity of SET types entering the domestic market. The use of SWH, solar PV systems, solar lighting systems, and solar mini-grid have appeared more frequently in literature over the last five years, while solar cookers stopped appearing after 2013. Also, this study found that a more significant proportion of the research is being conducted on solar system units instead of modular units. This result may indicate that SETs are now being developed to provide multiple energy functions and services. For example, solar cookers have potentially been succeeded by solar home systems, solar mini-grids, solar lighting systems. Among the reviewed articles, the most researched SET was solar PV systems, followed by solar water heaters and solar lights. This result may reflect that the research tended to focus on these SETs as they are frequently invested in and used in mass rural household solar electrification projects. Also, the results obtained resonate with the need for 'off-grid solutions that can address more than one energy need and that can be used easily instead of their coal electricity-powered equivalents by individual rural and low-income households. However, the development of new solar technologies and how successful they will be is based on trial and error; therefore, research should be encouraged on all SETs and not only mainstream technologies.

The analyses used to determine impact have diversified over the last five years. However, the focus and use of socio-economic analyses have been dominant over time as the primary analysis or a feature of the analysis used in one of the reviewed publications. The results are likely influenced by the MDG's could account for the initial focus on socio-economic impacts. In contrast, the introduction of the SDG's encouraged an integrated approach because progress towards one target is dependent on others, inadvertently requiring science and research to include the economic, social, technological, and environmental dimensions in order to achieve a holistic view of the impacts of solar technologies have on rural households and sustainable development. However, it is of concern that an analysis to capture all of the dimensions mentioned above was found in only six of the reviewed studies because of the effects in relation to the SLA. Socio-economic analyses capture not all the contributions towards the asset bases. While those studies included environmental aspects, the results of this study show that the recorded number of natural indicators are far less than what was led to believe from the title and abstract searches.

The analysis of the reviewed literature showed that the majority of studies used mixed-method approaches and field surveys for data collection. The use of this research approach may indicate how to establish the impacts of SETs on rural households most effectively and accurately based on the experiences of household members. In energy research, field surveys are often undertaken to establish, amongst others, the socio-demographic profiles, household energy profiles, behaviours, and energy needs. Mixed methods for impact evaluation allow more significant insights into how and why SET's as an intervention produced specific intended and unintended impacts and to what extent the individuals felt the impacts. In addition, surveys have the potential to identify all impacts made to the livelihoods of rural households, as the questions asked can be tailored to incorporate all the indicators identified in this study.

The geographic scope of study locations shows that the research done diversified across many different developing countries over time. This was especially the case for Africa and Asia, in which the most significant proportion of studies were conducted. While it is not conclusive, the high number of publications being conducted in Africa and Asia may indicate the level of interest and investment over time in wanting to develop and implement SETs for rural development. According to the global energy reports, developing countries will soon take the lead in renewable adoptions, but not all these countries are being represented in the research being produced. What is needed is a way to identify the projects being undertaken and ensure that impact research is being done on them if we are to get a true reflection of the progress or lack thereof being made by SETs in contributing to the development of rural livelihoods sustainably.

Change in this regard may be positive as it shows that researchers are broadening their vision of determining impacts. In addition, this change may positively reflect the growing interest and expansion that has taken place in researching these technologies and their implementation. This applies to all the changes identified in this study that have occurred over the last two decades. However, this change also brings with it a significant amount of variation. The extent of heterogeneity in the overall research designs allows for knowledge gaps, possible biases and restrictions, which will have had an impact on the results reported making it challenging to conduct meta-analyses.

5.2.3 Diversity and inclusivity of indicators and impacts

The third objective of this study was to determine the extent of both diversity and inclusivity that exists in the indicators used to determine impact concerning the SLA framework. From the reviewed articles, 610 impacts were recorded, and 27 indicators were identified. The indicator of the household economy was the only indicator that appeared in all studies, while 10 indicators appeared in 50% of the reviewed studies. However, no studies reported against all of the indicators identified. The results reveal that impact indicators that affected human capital were most used, followed by physical, financial, natural, and social factors, respectively. There was a significant difference in how often these indicators appeared, further highlighting the significant variation in how the impacts are determined. MaCarty and Bryden (2017) stated that technologies that are meant to provide energy services in such a way that they address technical, financial, environmental, and social aspects, and the technologies investigated in this study, none were investigated account for its impact on all livelihood capitals.

Indicators showing the impacts on the human capital base of rural households were the most diverse. The extent of the different variables used to measure the impacts on the human capital base of rural households were far greater than those used to measure impacts against the other capital bases. According to Fylaktos (2010), this should be expected as they explain, human capital is rarely examined as a direct measure given the different manifestations. Also, access to access to modern energy is set to have multidimensional influences on human capital. Similarly, in this study, only four human indicators, i.e., food security, quality of life, health, and education, were classified to make direct contributions to rural livelihoods. Over time, the most frequently occurring human indicators were an increase in the activities rural households engage in due to access to energy services, improved academic performance, increased time availability and flexibility, and decreased energy consumption behaviour and health risks. These findings are essential contributors to ensuring a sustainable livelihood as more educated, skilled and healthy individuals have a greater propensity for increased wealth creation (Fylaktos, 2010).

Based on the systematic review, physical indicators were the second most diverse measure of impact that focused on how energy provision contributed to physical capital. Most of the indicators are indirect as they contribute to the functioning of the SET. The significant mean impacts found that the quality of lighting improved, and an increase was recorded in light hours, communication and reports of positive attitudes, perception and experiences of SET. However, reported also was the poor operation and maintenance services despite the high percentage of households reporting that they receive spares and after-sales services. In addition, the household user's knowledge of operation and maintenance was reported to be poor. The latter findings, with respect to the SLA has a negative impact as long-term energy futures and increased capacities of rural low-income households as a result of receiving the benefits of SET's are dependent on maintenance support (Yadav et al., 2019).

While **financial** indicators were not as diverse as human and physical indicators, they did occur more often in the literature over time. The most common indicator used in every one of the reviewed studies was 'household economy', a financial indicator that looked at household savings, income, payback period, and other impacts that appeared to a lesser extent and could not be compared. The significant finding from the mean impact analysis found an increase in household savings and income. Included among the financial indicators were income-generating activities and productivity, which was both found to increase. Energy expenditure was found to have decreased. Essential to these findings is the understanding that determining the financial capital impacts may be easy to interpret and compare. However, it cannot always project an adequate determination of impacts, be it positive or negative, when a physical asset is introduced (Fylaktos, 2010).

From the classification, the natural indicators were lacking, given that the interrelationship between people and the **natural** environment is of the most significant importance for the livelihoods of rural households in developing countries. The indicators tended to focus on air quality, pollution, and environmental awareness while overlooking the impact on other natural assets like water and water quality, the reliance on wood, and deforestation, which is affected by previous energy behaviours and sources of energy. However, from the mean impacts, there was a decrease in pollution and increased environmental awareness and air quality. Similarly, the lack of diversity was found in the classification of **social** indicators as only two were found. Results showed an increase in social interactions and improved gender equality for women regarding opportunities to work and study, decision-making, and overall well-being. Lemaire

(2018) highlights that 'the quantification of the impact of access to electricity **on social** aspects within communities seems to also be an under-researched field, particularly on the social dynamics as the introduction of solar systems in a community and the potential increase of inequalities between owners of solar home systems and those who are left in the dark. Most surveys mention the importance of gender and found quantitative evidence of differentiated gender impacts in terms of time use'. In addition, this study finds that social in the context of the SLA differs from the collective term social given to account for both human and social indicators, which may account for the lack of indicators and a large number of human indicators found.

Another significant source of variation was apparent in the difference between the number of direct and indirect indicators and the number of quantitative and qualitative indicators used in the reviewed articles. According to the classification, most indicators were indirect, and there were more qualitative indicators used in the reviewed articles than quantitative. These results show that there is diversity amongst the impact indicators used over time; however, inclusivity is lacking. There were no studies that reported against all capital bases of rural livelihoods. Of concern are the implications of such a large extent of variation in determining the impacts of SET's on rural households. Although the same indicator was used, the differing contexts and how it was quantified made them incomparable. This is a notable finding given that each of the reviewed studies should contribute towards a holistic view of the impacts that these technologies have to inform relevant parties on how to develop these technologies further and how to implement them in the future. In addition, another primary concern that results from the above extent of variation inhibits the ability to compare the results of the studies to achieve a definitive list of positive and negative impacts of SETs. This was experienced when examining the meta-data to determine the mean results of the most frequently used indicators whereby the reported results were presented using various metrics.

5.3 Recommendations

The concerns emphasised in this chapter is based on the results and discussion of the systematic review and meta-analysis presented in the previous chapter. This section presents the main recommendations discussed briefly and in relation to the overall aim and objectives that informed this study.

- **Increase investment to generate more research on the impacts of SETs within the Global South.**
  Governments and research organisations, both local and international, should allocate funds to allow for further research to be undertaken to reduce the research gap, financial risk and uncertainty associated with SETs which may hinder their development and implementation.

- **Increase global attention to showcase the importance of SET research and its role in facilitating rural development**.
  As shown in this study, international energy conventions and conferences can facilitate the required stimulus to not only promote more research but shift the foci to be more inclusive of experiences in the Global South. This also has the potential to inform SET technological advancements to be more applicable and responsive to household energy needs.

- **Improve accessibility and availability of relevant SET research**.
  Although research is predominantly targeted for academic purposes, there is need for this information to be more accessible to other stakeholders, especially government officials who are tasked with energy planning and development. Perhaps the literature needs be disseminated to other databases to facilitate access. The information within these records have the potential to greatly enhance implementation, specifically when the focus is sharing the main lessons, opportunities and challenges associated SETs.

- **Encourage multidisciplinary approaches for the assessment of SET impacts**.
  It is widely established by the growing body of research, that socio-economic development through secured energy access has several benefits. By extending the scope of research through multi and transdisciplinary approaches, we may be able to deepen our understanding of how SETs enable livelihoods and to what extent. This may contribute to more efficient expenditure and investment due to more strategic selection of SETs. This may facilitated a more targeted approach, which in the context of the Global South, may be more effective given the widespread resource constraints.

- **The shared experiences of SETs also have the potential to inform design.**
  Future types of SET's need to be designed to address more than one energy need or provide more than one energy service. Therefore, it is recommended that SET's such as SWH, solar PV systems and other system units need be designed to become more efficient and more tailored to addressing the basic energy needs of rural households. The use of modular SET's such as solar cookers need to be reassessed to establish how the design should change to be suit the needs of rural households.

- **The use of diverse indicators have the potential to capture livelihood impacts broadly.**
  As reflected in the systematic review the use of diverse indicators that reflect the livelihoods more broadly is required when investigating the impacts of SET's on rural households. Diverse indicators will be better suited to account for all impacts that arise either directly or indirectly due to the multiple strategies rural households employ to increase their capital assets as a result of increased energy services.

- **Use mixed method approaches when assessing the SET impacts**
  The use of mixed methods that utilise both quantitative and qualitative measures of impact is recommended when investigating the impacts of SET's to capture the multi-dimensionality of energy poverty within the developing context. Important to establishing the true impacts is to understand the experiences and preferences of rural households as a result of using these technologies, as merely focusing on quantitative technical and physical impacts may result in developing a more efficient SET but that is not going to be used.

- **Increase the natural and social indicators when assessing the impacts of SETs in rural context.**
  The natural assets available to rural households form in most cases form basis of their ability to acquire other livelihood benefits. Therefore, the influence of SET's on natural capital cannot be overlooked. While social indicators, such as the establishment of community employment networks will also be influenced by large scale electrification programmes that require community to help promote and maintain these technologies within their communities.

- **The SLA and UNDG's definition of impact has the ability to guide future impact research.**
  The use of SLA and UNDG's definition of impact is recommended as a guide for future impact research as it provides a list of evaluators and criteria to assist in generating impact indicators, to include the influence on all five livelihood capitals. In addition, it allows flexibility and customisation required when investigating different SET's. A guideline to this effect could allow for future impact analyses to be diverse and inclusive enough to give a more accurate reflection of all possible impacts on rural households. This may inform future the selection of the most appropriate SET to be installed in rural households, which may subsequently encourage further investment and research.

- **Increase operation and maintenance of SET's provided to rural households.**
  The meta-analyses revealed that an increase in the operation and maintenance services provided to rural households that use SETs is required to ensure the technologies are working and that they are being used in order to actually have a positive impact. This can be done by increasing the user knowledge of operation and maintenance which was found to be lacking.

5.4 Concluding remarks

This study critically examined how research on the impacts of SETs on households in rural communities in the Global South have changed over time. A hybrid systematic review with elements of a narrative analysis was used to investigate the research elements of the reviewed studies and to critically evaluate of the indicators used in the reviewed studies and subsequent impacts. The main findings of this showed that the Global South was contributing a significantly lower amount of published research on the impacts of SETs on rural households compared to the global north countries. In addition, it was revealed that there were changes over time in the indicators used, the type of analyses used, the type of SETs investigated, and the geographic scope extends across sixteen developing countries. However, the use of mixed methods and field survey data collection approach largely stayed the same over the same period of time. Furthermore, despite there being a diverse amount of impact indicators used, it was revealed that over time there were no studies that simultaneously into consideration all possible effects on the human, social, physical, financial, and environmental impacts. As a result, an extensive amount of variation was present, which inhibited the identification of clear impacts from the most frequently used indicators.

A key contribution of this study is by using the UNDG's definition of impact and the SLA framework, the study showed how it is possible to account for all possible impacts of SET's on rural households. Furthermore, this study systematically contributes to the understanding of how research on the impacts of solar technologies has changed over time, and the recommendations will attempt to inform how the future evaluation of SET impacts should take place. The knowledge gained from this study may also inform the design of SET implementation strategies for households in low income and rural communities. Finally, the overall contribution of this study has highlighted the need for and importance of research to be undertaken on the impacts of SETs in ensuring rural household energy security and rural development.

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APPENDIX A:
CONTINUED SUMMARY OF REVIEWED LITERATURE

Year	Author(s)	Title	Times Cited	Study Location	Type of SET	Type of Unit	Type of Analysis	Type of Approach	Data Collection
2010	Naspolini et al.	The role and benefits of solar water heating in the energy demands of low-income dwellings in Brazil	72	Brazil	Solar Water Heater	Modular	Technical Socio-Economic	Mixed	Field Survey
2011	Wlokas	What contribution does the installation of solar water heaters make towards the alleviation of energy poverty in South Africa?	32	South Africa	Solar Water Heater	Modular	Socio-Economic	Qualitative	Field Survey
2011	Mondol and Klein	Impacts of solar home systems on social development in rural Bangladesh	89	Bangladesh	Solar PV system	System	Socio-Economic	Mixed	Field Survey
2012	Millinger et al.	Evaluation of Indian rural solar electrification a case study in Chhattisgarh	70	India	Solar Mini-Grid	System	Socio-Technical	Mixed	Field Survey
2013	Asaduzzaman et al.	Power from the sun: An evaluation of institutional effectiveness and impact of solar home systems in Bangladesh	38	Bangladesh	Solar PV system	System	Socio-Economic Environmental	Mixed	Field Survey
2013	Pinchot et al.	Solar Lighting Pilot Program for Shegerab Refugee Camp, Sudan	0	Sudan	Solar Lantern	Modular	Socio-Economic	Mixed	Field Survey
2013	Beltramo and Levine	The effect of solar ovens on fuel use, emissions and health: results from a randomised controlled trial	43	Senegal	Solar Oven	Modular	Social	Quantitative	Field Survey
2013	Harish et al.	Adoption of solar home lighting systems in India: What might we learn from Karnataka?	36	India	Solar Lighting System	System	Socio-Economic	Mixed	Field Survey
2013	Samad et al.	The benefits of solar home systems: an analysis from Bangladesh	77	Bangladesh	Solar PV system	System	Socio-Economic	Mixed	Field Survey
2014	Khandker et al.	Surge in solar-powered homes: Experience in off-grid rural Bangladesh	50	Bangladesh	Solar PV system	System	Socio-Economic Environmental	Mixed	Secondary and Field Survey
2014	Sapkota et al	Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal	49	Nepal	Solar Lighting System	System	Enviro	Mixed	Secondary Data
2015	Azimoh et al.	Illuminated but not electrified: Assessment of the impact of Solar Home System on rural households in South Africa	67	South Africa	Solar PV system	System	Socio-Economic	Mixed	Field Survey

2015	Yarime et al.	Introducing solar LED lanterns to rural Kenya: Sustainability assessment of environmental, economic, and social impacts	1	Kenya	Solar Lantern	Modular	Socio-Economic Environmental	Mixed	Field Survey
2015	Bensch et al.	Impacts of access to solar energy on rural households: An evaluation of a Netherlands supported programme in Burkina Faso	3	Burkina Faso	Solar PV system	System	Socio-Economic	Mixed	Field Survey
2015	Aigbavboa	Low-income housing residents' challenges with their government install solar water heaters: A case of South Africa	7	South Africa	Solar Water Heater	Modular	Technical Socio-Economic	Mixed	Secondary and Field Survey
2015	Murali et al	Socio-technical assessment of solar photovoltaic systems implemented for rural electrification in selected villages of Sundarbans region of India	8	India	Solar Mini-Grid	System	Socio-Technical	Mixed	Field Survey
2016	Grimm et al.	A First Step up the Energy Ladder? Low-Cost Solar Kits and Household's Welfare in Rural Rwanda	115	Rwanda	Solar Lighting System	System	Socio-Economic	Qualitative	Field Survey
2016	Mishra and Behera	Socio-economic and environmental implications of solar electrification: Experience of rural Odisha	52	India	Solar PV system	System	Environmental Technical Socio Economic	Qualitative	Secondary and Field Survey
2016	Rom et al.	The Economic Impact of Solar Lighting. Results from a randomized field experiment in rural Kenya	20	Kenya	Solar Lantern	Modular	Socio-Economic	Mixed	Field Survey
2016	Giglio and Lamberts	Savings related to solar water heating system: A case study of low-income families in Brazil	13	Brazil	Solar Water Heater	System	Socio-Economic	Mixed	Field Survey
2016	Hakiri et al.	Assessing the Role of solar home systems in poverty alleviation: Case study Rukungiri district in Western Uganda	3	Uganda	Solar PV System	System	Socio-Economic	Mixed	Field Survey
2016	Saimon and Ahasan	Effects of solar energy use on rural community: a study of Boyarjapha village in Paikgachha upazila	8	Bangladesh	Solar PV System	System	Socio-Economic Mixed	Mixed	Field Survey
2017	Curry et al.	The potential and reality of the solar water heater programme in South African townships: Lessons from the City of Tshwane	13	South Africa	Solar Water Heater	Modular	Socio-Economic Environmental	Mixed	Field Survey
2017	Kabir et al.	Social Impacts of Solar Home Systems in Rural Areas: A Case Study in Bangladesh	38	Bangladesh	Solar PV system	System	Social	Mixed	Field Survey
2017	Barman et al.	Performance and impact evaluation of solar home lighting systems on the rural livelihood in Assam, India	50	India	Solar Lighting System	System	Technical Socio-Economic	Mixed	Field survey
2017	Naspolini and Ruther	Impacts of Domestic Solar Water Heating (DSWH) systems on the cost of a hot shower in low-income dwellings in Brazil	12	Brazil	Solar Water Heater	Modular	Techno-Economic	Mixed	Field Survey

2017	Chen at al.	Welfare impacts of an entry-level solar home system in Uganda	7	Uganda	Solar Lighting System	System	Socio-Economic	Mixed	Field Survey
2017	Sadiq	Solar water heating system for residential consumers of Islamabad, Pakistan: A cost benefit analysis	26	Pakistan	Solar Water Heater	Modular	Economic	Mixed	Secondary
2017	Niu et al.	Assessing the Potential and Benefits of Domestic Solar Water Heating System Based on Field Survey	3	China	Solar Water Heater	Modular	Socio-Economic	Mixed	Field Survey
2017	MacCarty and Bryden	Costs and impacts of potential energy strategies for rural households in developing communities	17	Mali	Solar PV system	System	Technical Socio-Economic	Mixed	Field Survey
2017	Aklin et al.	Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India	91	India	Solar Mini-Grid	System	Socio-Economic	Quantitative	Field Survey
2017	Islam et al.	Evaluation of solar home system (SHS) implementation in Harirampur subdistrict	6	India	Solar PV system	System	Techno-Economic	Mixed	Secondary and Field Survey
2018	Naidoo and Munien	The socio-economic impacts of solar water heaters compared across two communities: A case study of Cato Manor	5	South Africa	Solar Water Heater	Modular	Socio-Economic	Mixed	Field Survey
2018	Lemaire	Solar home systems and solar lanterns in rural areas of the Global South: What impact?	19	Global South	Solar PV system/ Lantern	System	Socio-Economic	Qualitative	Secondary
2018	Constantino et al.	Adoption of Photovoltaic Systems Along a Sure Path: A Life-Cycle Assessment (LCA) Study Applied to the Analysis of GHG Emission Impacts	16	Brazil	Solar PV System	System	Enviro-Technical Socio Economic	Quantitative	Secondary
2018	Gray et al	The power of small-scale solar: gender, energy poverty, and entrepreneurship in Tanzania	4	Tanzania	Solar Lighting System	System	Socio-Economic	Mixed	Field Survey
2019	Sharma et al.	Do solar study lamps help children study at night? Evidence from rural India	8	India	Solar Lighting System	System	Socio-Economic	Mixed	Field Survey
2019	Huq	Solar energy Fuels for Sustainable Livelihoods: Case Study of Southwest Coastal Region of Bangladesh	1	Bangladesh	Solar PV system	System	Technical Socio-Economic	Mixed	Field Survey

2019	Yadav et al.	The prospects of decentralised solar energy home systems in rural communities: User experience, determinants, and impact of free solar power on the energy poverty cycle	17	India	Solar Lighting System	System	Socio-Technical	Mixed	Field Survey
2019	Ibrik	An overview of electrification rural areas in Palestine by using micro-grid solar energy	5	Palestine	Solar Mini-Grid	System	Technical Socio-Economic	Quantitative	Field Observation
2019	Jensen et al.	Assessing the Impact of Off-grid Solar Electrification in Rural Peru: Replicability, Sustainability and Socioeconomics	3	Peru	Solar PV system	System	Socio-Technical	Mixed	Field Survey
2019	Al-Smairan	Socio-economic effects of solar home systems in Jordan Badia–A case study in Rawthat Al-Bandan village	1	Jordan	Solar PV system	System	Socio-Economic	Mixed	Field Survey
2019	Liu et al.	Evaluating potentials of passive solar heating renovation for the energy poverty alleviation of plateau areas in developing countries: A case study in rural Qinghai-Tibet Plateau, China	11	China	Solar Passive Heating	System	Technical	Quantitative	Field Survey

APPENDIX B:
CONTINUED SUMMARY OF REVIEWED LITERATURE

Impacts	No. Articles Recorded	Impact 1	Impact 2	Impact 3	Mean Result
Water Consumption	10	Increase = 60 %	Decrease = 30 %	No affect = 10 %	60% Increased
Quality of Light	13	Increase = 92 %	Decrease= 8 %	No affect = 0 %	92% Increased
Productivity	15	Increase = 67 %	Decrease = 0 %	No affect = 33 %	67% Increased
Household Income	9	Increase = 100 %	Decrease = 0 %	No affect= 0 %	100% Increased
Solar Potential	3	High = 67 %	Low = 33 %	-	67% High
Durability	2	7 Years	20 Years	-	13.5 Years
Hot Water Supply	5	Increase = 80 %	Decrease = 20 %	No affect = 0 %	80% Increase
Indoor Air Temperature	4	Increase = 50 %	Decrease = 0 %	No affect= 50 %	50% Increase/No Affect
Payback Period					83% ≥ 5 years
Energy Output	3	Good = 67 %	Inconsistent = 33%	-	67% Good
Sanitation	3	Improved = 100 %	Decrease =0 %	No affect = 0 %	100% Improved
Energy Expenditure	19	Increase= 26 %	Decrease= 74 %	No affect = 0 %	74% Decreased
Quality of Life: Poverty and Vulnerability	10	Increase = 80 %	Decrease = 0 %	No affect = 20 %	80% Increased
Household Safety	11	Improved = 73 %	Decrease = 18%	No affect = 9 %	73% Improved
Social Interactions	7	Increase = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased
Access to Information	10	Increase % = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased

Impacts	No. Articles Recorded	Impact 1	Impact 2	Impact 3	Mean Result
Technical Problems Experienced	12	Yes = 83 %	No = 17 %	-	83% Yes
Alternate Appliance Use	9	Increase = 22 %	Decrease = 56 %	No affect = 22 %	56% Decreased
Knowledge of operation/ management	11	Good = 9 %	Poor = 64 %	None= 27 %	56% Poor
Lighting Facilities	8	Increase = 88 %	Decrease = 12 %	No affect = 0 %	88% Increased
Pollution	15	Increase = 0 %	Decrease = 93 %	No affect = 7 %	93% Decreased
Income Generating Activities	19	Increase= 79 %	Decrease = 0 %	No affect= 21 %	79% Increased
Study Hours	22	Increase = 91 %	Decrease = 0 %	No affect = 9 %	91% Increased
Operational Maintenance	20	Good = 25 %	Poor = 60 %	No affect = 15 %	60% Poor
Education: Academic Performance	12	Improved = 100 %	Decrease = 0 %	No affect = 0 %	100% Improved
Kerosene Expenditure	10	Increase = 0 %	Decrease= 100 %	No affect = 0 %	100% Decreased
Indoor Air Quality	9	Improved = 67 %	Decrease = 0 %	No effect = 33 %	67% Improved
Communication	4	Increase = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased
Spares-After-sales Services	5	Provided = 80 %	Not Provided= 20 %	-	80% Provided
Functionality Status					87% Working
Alternate Light Source expenditure	2	Increase = 0 %	Decrease = 100 %	No affect = 0 %	100% Decreased
Energy Consumption	8	Increase= 13 %	Decrease = 87 %	No affect = 0 %	87% Decrease

Impacts	No. Articles Recorded	Impact 1	Impact 2	Impact 3	Mean Result
Environmental Protection Resource Conservation	4	Increase = 100 %	Decrease = 0 %	No affect= 0 %	100% Increased
Water Temperature	2	Increase = 50 %	Decrease = 0 %	No affect = 50 %	50% Increased/No affect
Employment	2	Increase = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased
Household Satisfaction and Experience	4	Positive = 75 %	Negative = 25 %	-	75% Positive
Community Skills Development	2	Increase = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased
Appliance Ownership	1	Increase = 100 %	Decrease = 0 %	No affect = 0 %	100% Increased
Cooking Services	3	Improved = 67 %	Decrease %= 0 %	No affect = 33 %	67% Improved
Food Security	2	Increase = 100 %	Decrease = 0 %	No affect= 0 %	100% Increased
Battery Capacity and Performance Ratio	2	Good = 100 %	Poor = 0 %	No affect = 0 %	100% Good
Household Savings	22	Increase = 91 %	Decrease = 0 %	No affect = 9 %	91% Increased
Activities Engaged	31	Increase = 94 %	Decrease= 0 %	No affect = 6 %	94% Increased
Light Hours	17	Increase = 70 %	Decrease = 18 %	No affect = 12 %	70% Increased
Time	25	Increase = 76 %	Decrease = 16 %	No affect= 8 %	76% Increased
Operating Period					30% (1-2Years)
Health Risks	21	Increase = 0 %	Decrease = 95 %	No affect = 5 %	95% Decreased
Kerosene Consumption	19	Increase = 0 %	Decrease = 100%	No affect = 0 %	100% Decreased