

**MEDIATING TRANSITION TO HOUSEHOLD ELECTRICITY CONSERVATION
THROUGH CO-DESIGNING IN MAKHANDA, SOUTH AFRICA**

**By
Uzziah Mutumbi**

**Thesis submitted in the fulfilment of the requirements for the degree of
Master of Science
at
Rhodes University**

Department of Environmental Science
Rhodes University
Makhanda
South Africa

November 2021

Declaration

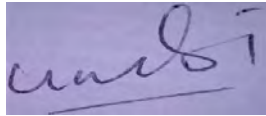
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Abstract

Households consume up to 20% of total global electricity consumption, hence they are important role players in efforts for promoting sustainable consumption. Research on electricity-use behaviour and effectiveness of interventions is important for informing intervention strategies. However, relative to developed countries, research on this subject is lacking in developing countries, where electricity access is limited, and a substantial proportion of households are energy poor. The main goal of this study was to examine reported electricity-use behaviour and the effects of co-designed interventions on household electricity consumption in low-income households in Makhandla, South Africa, using a field-based experiment. Findings from self-reported electricity-use practices showed mixed results, with households reporting both good electricity-use behaviour (e.g., cooling down hot food before refrigeration) and wasteful actions (e.g., leaving appliances on standby). Results showed that electricity-use behaviour was influenced by socio-psychological values including universalism, benevolence, hedonism, and power. Over the intervention period, households exposed to co-designed electricity-saving interventions showed mean electricity savings of about 5.5%, while households in the Partial Treatment and Control group showed increased electricity consumption. Socio-demographic factors such as age and psychological factors (involvement and perceived behavioural control) were very important determinants of household consumption. Broadly, the findings empirically validate the impact of collective problem formulation and co-designing interventions in promoting sustainable actions.

Keywords: Electricity use, households, behaviour, co-design, sustainability, reported behaviour, interventions.

Acknowledgments

Special thanks to the Almighty God for the gift of life and strength, throughout the course of this study. I dedicate this work to my mother, Sarudzai Mutumbi, who passed away just three months after I started this journey. May your dear soul rest in eternal peace. I also would like to thank my family members, especially my father, Paul Mutumbi, and my two sisters, Caroline, and Ebenezer, together with their families for providing me with the emotional support, without which I would not be standing today. I also would like to thank my supervisors, Professor Gladman Thondhlana and Dr. Sheunesu Ruwanza and their families, for the priceless academic and emotional support they provided over the course of the study. Special thanks also go to the Forward in Faith Ministries International church members for all the love and support which helped me to settle in Makhanda; may the Almighty God bless them. Special thanks to the Rhodes University Department of Environmental Science for providing a nurturing environment for me to realise my full potential. Special thanks, too, to the Leading Integrated Research for Agenda 2030 in Africa (LIRA 2030) who funded this project, without which it would have been impossible to complete my research. Lastly, I thank my officemates and friends from the Department of Environmental Science, Rhodes University for all their support.

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Chapter 1: Introduction

1.1 Study motivation

Ensuring sustainable electricity is a major concern in the cities of developing countries where rapid urbanisation and, consequently, resource consumption has serious social, economic, and environmental impacts (Ntuli, 2019; World Bank, 2020). Global estimates suggest that the residential sector is a major consumer of electricity, accounting for over 20% of the overall electricity demand (Energy Information Administration, 2019). Thus, households are becoming a targeted group in electricity debates not only because they consume a notable percentage of global electricity, but they are also major emitters of greenhouse gases, leading to global warming (Trotta, 2018). Consistent with global trends, the South African residential sector consumes about 20% of overall electricity produced (Eskom, 2019).

South Africa's energy sector generates 85.7% of its energy from locally acquired low-quality coal, 0.6% from solar, 5.2% from nuclear, 3.2% from natural gas, 1.7% from diesel, 0.9% from wind and 2.4% from other sources (Statistics SA, 2016). Through the government's initiative to provide citizens with access to basic services, such as electricity and water in 2000, the country's rate of electrification rose from only 36% in 1993 to 75% in 2009, with 88% of those in the urban areas and 55% in the rural connected to the national grid (Niez, 2010). Currently, more than 90% of South African households are connected to the grid, making the country one of the most energy-intensive countries on global ratings; however, the country is energy insecure owing to demand outstripping supply (Eskom, 2019; 2020).

Efforts by the energy sector and the government to establish an equilibrium between supply and demand have been largely directed towards implementing technical interventions. For example, the Department of Energy is spearheading investments in wind and solar energy throughout the country (Department of Energy South Africa, 2019). Efforts have also been directed towards economic interventions. For example, in 2018 the primary electricity provider in South Africa, Eskom, applied to the National Energy Regulator of South Africa (NERSA) for a 15% increase in tariffs for the years 2019, 2020 and 2021 (Eskom, 2019). The government, together with Eskom, have invested over ZAR160 billion (US\$85.56 billion) towards the construction of the Kusile and

Medupi power stations since the year 2007 (Department of Energy South Africa, 2019). Such interventions are quite unsustainable considering that Eskom is in a financial crisis (Eskom, 2020). Moreover, such interventions are not sustainable, considering the predicted rapid growth of the BRICS (Brazil, Russia, India, China, and South Africa) economies (Azevedo et al., 2018). Behavioural interventions can offer long-lasting and cheaper ways of reducing household electricity consumption (Kua and Wong, 2012; Williams, 2021).

Increasing evidence suggests that reducing household electricity-use can yield positive socio-economic and environmental benefits (Abrahamse et al., 2005; Steg, 2008; He and Kua, 2013; Thondhlana and Kua, 2016). For example, reductions in electricity consumption can result in reduced bills (Thondhlana and Kua, 2016), and reduced electricity demand which can minimise interruption to electricity supply (Setlhaolo and Xia, 2016) and households' carbon footprints (Azevedo et al., 2018). The social and economic costs of unsustainable electricity consumption are substantial and can be seen in households spending a large amount of their income on purchasing electricity. There is also an increase in the resources required to build more power plants and to mitigate the greenhouse effects on the environment (Department of Energy South Africa, 2019; Eskom, 2019). These costs point to the need for supporting existing technical and economic measures with behavioural interventions for sustainable electricity consumption.

1.2 The South African context

Consistent with global trends, unsustainable electricity production and consumption is a huge challenge in developing economies such as South Africa, where households make a considerable contribution to electricity demand (Winkler et al., 2006; World Bank, 2020; Ntuli, 2019). In South Africa, households consume around 20% of national total electricity needs, with serious implications for grid stability, energy security and greenhouse emissions (South Africa Energy Sector Report, 2018). South Africa is considered an energy-intensive country, which solely depends on depletable fossil fuels for electricity production. Consistent with other emerging BRICS economies (Brazil, Russia, India, China, and South Africa), the country's economy is largely dependent on and generates more than 90% of its electricity from low-cost coal (Eskom, 2018; Department of Energy, 2019; International Energy Agency, 2019). Since it produces electricity from locally available coal deposits, South Africa is known for providing the cheapest

electricity on the African continent (Department of Energy, 2012). However, despite the availability of affordable electricity, more than 47% of households in South Africa are energy insecure, spending between 14-17% of their gross monthly earnings on electricity (Odeku and Meyer, 2019). This electricity expenditure is above the acceptable threshold of 10% of monthly income, implying that close to half of South African households are energy poor (Department of Energy SA, 2012). González-Eguino (2015) defines energy poverty as the lack of access to adequate, reliable, affordable, and clean energy to support socio-economic development. Energy poverty directly influences households' socio-economic activities as it deprives the household of access to some of the goods needed for optimum survival (Department of Energy SA, 2012). In worst-case scenarios, households resort to alternative cheap sources of energy which are deemed unhealthy for both human wellbeing and the environment (Musango, 2014).

South Africa is among the top 20 greenhouse emitters globally and is the biggest emitter on the African continent (Green, 2019; World Bank, 2020). The International Energy Agency (2019) states that South Africa alone produces more than 55% of Africa's carbon dioxide emissions owing to its heavy reliance on low-quality coal. There are negative impacts associated with the reliance on low-quality coal which include land degradation, and air and water pollution which result in several environmental and socio-economic challenges to society (Burt et al., 2013). Moreover, the conversion of thermal energy to electricity is quite expensive, considering the financial state of Eskom. Thus, South Africa has become a major player in global debates on energy sustainability, particularly those focused on pathways towards transition to sustainable electricity use. The country faces the dilemma of providing sufficient electricity and mitigating the negative effects of fossil-dependent electricity production (Douglas and Schäffler, 2006; Wolpe and Reddy, 2015).

1.3 Research aims and conceptual framework

Literature across the globe highlights a considerable effort by electricity stakeholders and researchers to achieve sustainable cities through behavioural interventions (Thondhlana and Kua, 2016; Ssozi-Mugarura et al., 2017; Nahiduzzaman et al., 2018). However, there is little work that looks at transition to electricity-saving behaviour through co-production of knowledge and co-design of interventions (Ambole et al., 2019). Many interventions for encouraging electricity savings are arguably externally driven and unsustainable because they are seldom designed with

input from electricity suppliers and users (Coffey and Klein, 2016; Batinge and Musango, 2017; Ambole et al., 2019). Although these interventions may be useful in reducing consumption, they may lack social relevance as users may not identify with them. Second, there is limited research that focuses on the persistent effect of interventions (He and Kua, 2013; Thondhlana and Kua, 2016), and therefore, there is a need for more research that focuses on electricity-use behaviour and its determinants, as well as on examining the influence of co-design in the transition to electricity conservation at the household level. The motivation behind this thesis is to explore how household electricity-use behaviour can be altered towards sustainable consumption through collaborative mechanisms and user-driven interventions.

This study aims to advance the field of transdisciplinary studies more generally, and pro-environmental behaviour more specifically, through exploring electricity-use behaviour and transition to electricity saving through knowledge co-production processes and co-design of interventions with relevant stakeholders. The research aims to better understand how sustainable electricity transitions can be achieved through collaborative arrangements between residents, local city authorities, and electricity providers in Makhanda (Grahamstown), South Africa. The project is part of a broader research initiative in African cities under the Leading Integrated Research for Agenda 2030 in Africa (LIRA 2030) programme. The project was designed to test a conceptual model of transition to household electricity-saving behaviour based on knowledge co-production and co-designing intervention framing among low-income households in Makhanda, South Africa. The following research questions were designed to address these aims:

- What is the current state (progress and prospect) of household electricity-use research in South Africa?
- What is the reported electricity-use behaviour in households, and what factors influence it?
- What is the effect of co-designed interventions on household electricity consumption?
- Based on the findings, what are the implications for assumptions and constructs underlying pro-environmental behaviour, and the practical implications for local-level transition to sustainable electricity use?

1.4 Chapter outline

This thesis is made up of five chapters, three of which are empirical chapters. One of the empirical chapters is published and the remaining are still in the review process. In all the chapters, the author was responsible for creating drafts, data analyses procedures, and writing. Supervisors (who also co-authored the empirical chapters) assisted in planning and giving constructive suggestions. Since the thesis consists of empirical chapters with co-authors, they are written in the first-person plural (we) with the student (U. Mutumbi) as the first and the corresponding author of all the submitted chapters. This thesis outline is as follows:

Chapter 1 introduces the study, provides context, and gives an outline of the thesis. Chapter 2 reviews literature on household electricity-use behaviour research and interventions in South Africa as a basis for identifying progress to date and mapping future prospects. The chapter is entitled “Household electricity-use behaviour and interventions in South Africa: A scoping review”. The contributors are U. Mutumbi, G. Thondhlana and S. Ruwanza (submitted to *Sustainability: Science, Practice and Policy*). Chapter 3 examines reported electricity-use behaviour and the factors influencing it among low-affluent households in Makhanda, South Africa. Insights from this study were used to co-design electricity-saving interventions. The paper is entitled “Reported behavioural patterns of electricity use among low-income households in Makhanda, South Africa”. The contributors are U. Mutumbi, G. Thondhlana and S. Ruwanza. The paper has been published in the journal *Sustainability*. Chapter 4 examines the effects of co-designed behavioural interventions on electricity use among low-income households. The chapter is entitled “Co-designed interventions yield significant electricity savings among low-income households in Makhanda, South Africa”. The contributors are U. Mutumbi, G. Thondhlana and S. Ruwanza. Chapter 5 synthesises the findings and provides recommendations and conclusions.

Chapter 2: Household electricity-use behaviour and interventions in South Africa: A scoping review

Abstract

Globally, there are significant concerns related to the role of households in minimising electricity consumption and, in turn, greenhouse gas emissions. However, even though South Africa is a major energy consumer and greenhouse gas emitter, there has been no systematic analysis of the state of household electricity-use behaviour and interventions, making it difficult to identify progress and prospects. We conducted a scoping review of articles published between 2000 and 2021 to examine the current state of household electricity behaviour and intervention research and prospects. The findings showed that a substantial number of the studies reviewed focus mainly on electricity-saving interventions while very few studies focus on electricity-use behaviour. Further analysis of interventions showed that economic and technical measures were the most frequently reported, while behavioural interventions were reported least often. The keys gaps identified in the review include a limited focus on household electricity-use behaviour, the effects of behavioural interventions for promoting electricity conservation, and little attention to co-designing interventions. We conclude by highlighting future research needs about household electricity conservation.

Key words: Electricity-use, behaviour, households, research progress, co-design, sustainability.

2.1 Introduction

Access to energy is a basic human right but unsustainable production and consumption of electricity remains a significant global problem, with severe environmental and socio-economic implications (Tully, 2008; Ivanova et al., 2016; Williams et al., 2020). The environmental and socio-economic consequences of unsustainable electricity consumption and production are quite substantial, and can be seen in the associated greenhouse emissions, and in energy insecurity and poverty. Estimates suggest households account for more than 20% of total global energy demands (Song et al., 2019; Energy Information Administration, 2019) and are major emitters of greenhouse gases (Abrahamse et al., 2005). Thus, the residential sector is an important stakeholder in electricity research policy debates. The amount of electricity that is consumed daily in a typical

household setting has a direct impact on electricity demand. Thus, unsustainable electricity consumption can pose serious repercussions to households' electricity expenditure and the national grid. Wasteful electricity-use activities often result in high electricity bills, load-shedding when electricity demand outstrips supply, and negative environmental impacts from carbon emissions. Hence encouraging pro-environmental electricity-use behaviour, such as completely switching off gadgets when not in use and turning off lights when not needed, can reduce such impacts. However, pro-environmental electricity-use actions need to be rehearsed repeatedly until they become habits. Nilsen et al. (2012: 1) define habits as "...substrates of behaviour that are repeated until they become more or less automatic, enacted without purposeful thinking, largely without any sense of awareness".

Daily household electricity-use habits, for instance, leaving lights on when not needed, overloading the refrigerator (Benders, et al., 2006) and leaving appliances like stereos and decoders on standby mode (Olatunji et al., 2019) can result in unconscious electricity losses. Thondhlana and Kua (2016) and Mtutu and Thondhlana (2016) found that electricity users are generally reluctant to completely switch off appliances such as computers, chargers, decoders, televisions and speakers when they are not being used, which leads to 'vampire losses'. These 'vampire losses' are defined as hidden electricity losses as a result of leaving appliances on standby mode (Sahin and Koskal, 2014; Olatunji et al., 2019; Gerber et al., 2019). Most developed countries in the European Union have implemented several electricity efficiency strategies (e.g., appliance labelling) aimed at curtailing vampire losses incurred from appliances that use standby electricity (Blok, 2005). However, such interventions can be costly to low-income households, who are unable to buy energy-efficient gadgets (Department of Energy SA, 2018). Moreover, technical interventions cannot address wasteful electricity-use habits (Langevin et al., 2013). For example, households might have energy-efficient appliances but the sheer number of 'efficient appliances' can erode the benefits of efficient technologies, leading to unsustainable household electricity consumption.

A growing body of evidence suggests that electricity-use behavioural change at the household level can yield positive socio-economic and environmental benefits (Abrahamse et al., 2005; Steg, 2008). Electricity saving at the household level is important because the benefits can accrue

directly to households in reduced electricity bills (Heffner, 2011; Musango, 2014; Thondhlana and Kua, 2016), and can minimise electricity demand reducing electricity supply interruptions (Nel et al., 2016) and reducing households' carbon footprint (Wang and Meng, 2019). Though the benefits for reduced electricity consumption may not be visible at household level, given the degree of household electricity consumption on daily activities, the aggregate benefits of uninterrupted supply of electricity and a decrease in the carbon footprint are arguably considerable. Thus, the residential sector represents an important actor and a target for debates and practice on transition towards sustainable electricity use.

Sustainable electricity use can be achieved by understanding electricity-use habits and behaviour, the factors influencing behaviour (Nilsen, et al., 2012; Williams et al., 2020), and by embracing a holistic approach that integrates all the actors, including households and electricity providers (Du Plessis, 2015; Ambole et al., 2019), since they all have an interest in electricity as consumer and suppliers, respectively. Adopting such a holistic approach may help to identify and optimise opportunities from synergies and interconnections between actors. Ambole et al. (2019) have shown a positive association between co-designing electricity interventions and sustainable consumption. Co-designed interventions have a high probability of being accepted since the electricity consumers feel that they own the interventions (Ambole et al., 2019). Moreover, allowing consumers a chance to craft interventions can allow alignment of research goals and local realities, needs and priorities (Morgan et al., 2018). Promoting pro-environmental electricity use at the household level through behaviour change interventions is a promising avenue for engendering transition to sustainable electricity consumption. Increasingly, research now focuses on investigating household electricity-use behaviour and its determinants and interventions for electricity savings (Hori et al., 2013; Frederik et al., 2015; Zhou and Yang, 2016).

Large data sets of electricity consumption behaviour, determinants of behaviour, and electricity-saving interventions at the household level can help in identifying wasteful electricity-use practices, and in developing predictive models and co-designing pathways towards sustainable transitions. However, research on household electricity use tends to be less prevalent in developing countries, particularly in Africa. Most studies of this nature have been done in industrialised contexts (Klein and Coffey, 2016; Batinge et al., 2016; Ambole et al., 2019) and may not be

applicable to developing contexts. In South Africa, research on this subject tends to be fragmented at best and aspect-specific at worst, which makes it difficult to identify research advances, gaps, and prospects in the field of household electricity-use behaviour and the interventions needed for developing a common framework for transition to sustainable electricity use.

Against this background, this scoping review paper provides a comprehensive analysis of research trends on household electricity use in South Africa. The significance of this research is twofold. First, transition to sustainable electricity use is a growing research field globally, particularly in South Africa, where electricity production is dependent on fossils, and the environmental and social effects of unsustainable practices cannot be over emphasised. Second, this review may offer important observations on prospective research niches, especially as the country is faced with unique electricity challenges. Within the context of global and regional electricity research, a specific emphasis on South Africa can provide knowledge that is more relevant and applicable to the South African context. Considering this background, the main objective of this paper was to examine progress on household electricity-use behaviour and intervention research, identify research gaps, and map prospects for future research in South Africa, using a scoping review methodology (Arksey and O'Malley, 2005). The specific research questions are: What conceptual insights have been explored in household electricity-use research in South Africa? What is the current understanding on household electricity use and interventions for sustainable use? Based on the findings, what is the potential for co-developing behavioural interventions for promoting household electricity use?

2.2 Methods

2.2.1 Data collection

Scoping reviews seek to provide an overview of a research area to identify the amount of literature as well as gaps that exist (Tricco et al., 2016). The data-gathering phase was two-fold. First, a comprehensive, organised search of common academic electronic search engines, Google Scholar, Sabinet, Web of Science and Scopus was undertaken (Table 2.1). Searches in these databases were performed using key words, phrases or combinations of words, including “household electricity” OR “household electricity use” OR “household energy use” OR “household energy” OR “residential electricity use” OR “residential energy use” “South Africa” (see Falayi et al., 2021).

The article search was limited to journal articles, conference proceedings, government reports and theses published between 2000 and 2020. The timeframe was specifically selected to capture a collection of older research as well as newly emerging studies to diversify our understanding of trends over the past 20 years. It is important to note that, over the past few years, there has been a debate on whether Google Scholar can be used in literature reviews (Anderson, 2006; Gehanno et al., 2013). Although Google Scholar has numerous limitations, as suggested by Anderson (2013), in this research it did provide relevant publications that could not be retrieved from other databases.

Table 2.1 Databases and search commands used

Database	Search command used
Web of Science	TS=("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" AND "South Africa") AND TI=("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" AND "South Africa") AND AB=("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" AND "South Africa") AND AK=("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" AND "South Africa")
Google Scholar	allintitle: "household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" "South Africa"
Sabinet	Anywhere = ("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" "South Africa")
Scopus	TITLE-ABS-KEY = ("household electricity" OR "household electricity use" OR "household energy use" OR "household energy" OR "residential electricity use" OR "residential energy use" "South Africa")

The initial search returned about 384 articles, but after removing duplicates and irrelevant articles that did not meet the inclusion criteria, the process yielded 183 articles (Figure 2.1). However, reading the abstracts of these papers revealed that the key search terms used also brought up some irrelevant literature. For example, some papers focused on renewable energy and other forms of energy, such as nuclear. A further review of the articles was done to sift out irrelevant papers and to include relevant additions; the research retained 26 household articles based on coal-powered electricity. All papers on electricity use which focused on contexts other than households (e.g., industrial, commercial and university settings) were excluded. Reference lists of the remaining articles were evaluated with the aim of finding more related literature for the review, following MacPhail and Colla (2020), and the search returned a total of 36 articles. The articles were subdivided into work packages and analysed according to their respective focus as electricity-use behaviour; factors influencing electricity-use behaviour; interventions or demand response strategies and their effectiveness; the existence of partnerships for co-design of interventions and knowledge co-production, and other relevant features. The data collection process and stages are summarised in Figure 2.1.

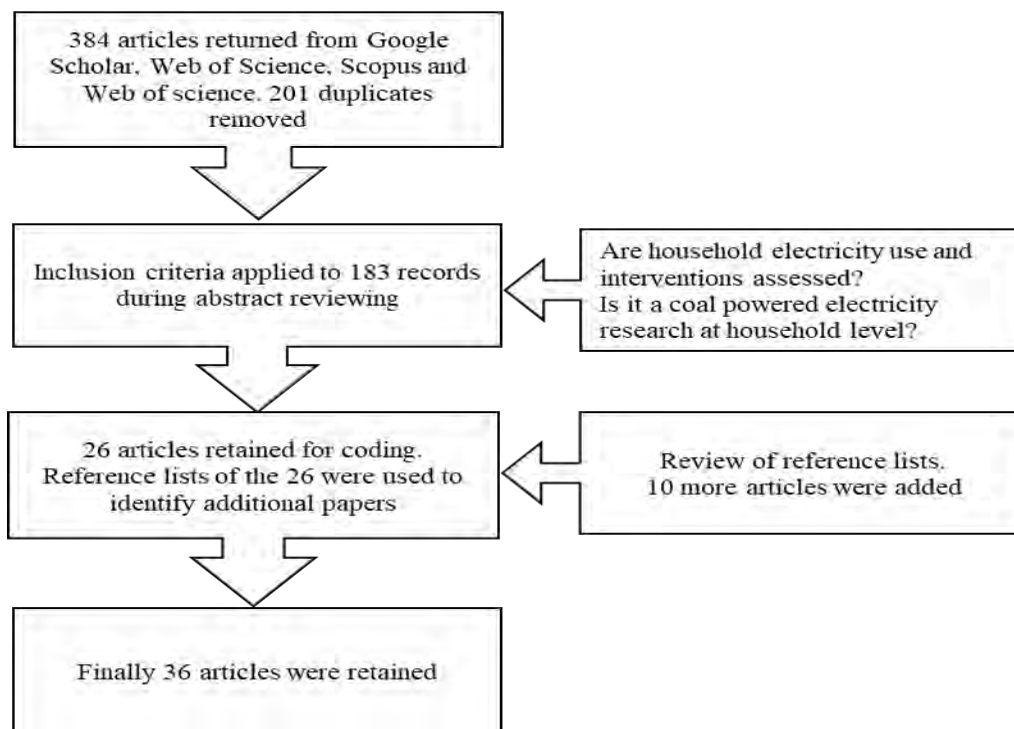


Figure 2.1 Search chart with decision tree showing how the review papers were selected.

2.2.2 Data analyses

Descriptive data analysis in the form of tables was performed to show the distribution of articles based on identifiers, such as type of publication (grey literature, including theses or journal articles); year of publication and conceptual focus of the articles, including electricity-use behaviour; determinants of behaviour and interventions for electricity consumption reduction, among others. To explore the conceptual focus and insights of the articles further, the text was analysed to answer the following research questions: What are the main themes discussed or addressed in the articles? What household electricity-use problems are identified and what electricity-saving interventions are suggested? Are the interventions user driven and what is the extent of focus on behavioural interventions as a pathway for promoting household electricity savings?

To provide further analytical insights, additional details were recorded from the articles. Thematic coding was used to align texts with the guiding questions. Despite the rigorous effort to include all relevant literature for this study, there are two potential limitations that should be considered. First, other published materials might have been left out in the search due to indexing errors, that is, the search criteria used. Second, some unpublished manuscripts might not have been publicly available at the time of the search, which might have resulted in their exclusion from the analysis. However, despite these possible limitations, the study provides potentially useful insights into the state of research on household electricity-use behaviour and intervention research in South Africa.

2.3 Results and discussions

2.3.1 Characterisation of reviewed articles

Table 2.2 shows the distribution of the reviewed articles with respect to the type of article, period of publication, socio-demographic focus, conceptual focus and scale of analysis, and types of electricity-saving interventions. Of all the articles reviewed, about 72% were journal articles and the remainder were grey literature including reports, theses, and conference proceedings. Regarding the distribution of articles by period of publication, the findings showed incremental growth between 2000 and 2020. However, a substantial proportion of articles (more than 75%) were published after 2011. Very few articles focused on electricity use by demographic group

(only one each for low-income and high-income households). Most of the articles assessed electricity use at national rather than district or municipal level.

Table 2.2 Descriptive features of the reviewed articles

Attribute	Proportion (%)
Type of article (n=36)	
Journal articles	72
Grey literature	28
Period of publication (n =36)	
2000–2005	3
2006–2010	19
2011–2015	31
2015–2020	47
Socio-demographic focus (n=36)	
Low-income households	4
High-income households	4
National focus	92

2.3.2 Conceptual perspectives

Only four articles (about 11%) focused on electricity-use behaviour (Nel et al., 2016; Thondhlana and Kua, 2016; Berkouwera, 2020; Williams et al., 2020). A third (33%) focused on the determinants of electricity-use behaviour (Figure 2.2). Over a sixth of the articles (64%) were based on electricity-saving interventions, while only two articles, Du Plessis (2015) and Ambole et al. (2019) focused on partnerships and co-designing.

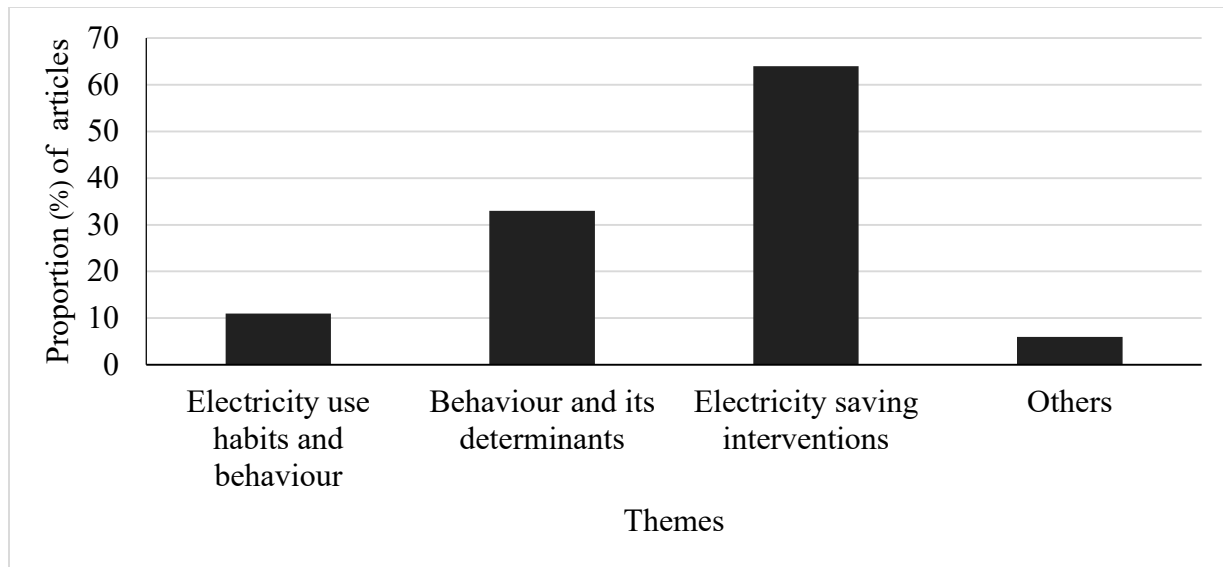


Figure 2.2 Conceptual perspectives of the reviewed papers

Electricity-use behaviour

Disaggregation of articles on household electricity-use behaviour showed that only two articles examined all household electricity-use actions (Thondhlana and Kua, 2016; Williams et al., 2020). Thondhlana and Kua (2016) recorded substantial changes in electricity consumption in response to varied behavioural intervention treatments. Williams et al.'s (2020) study on high-income households in Johannesburg showed that, while some households practised electricity-saving behaviour, there was evidence of wasteful behaviour ranging from not turning off heaters to leaving electronic gadgets on standby mode. Only one article (Nel et al., 2016) reported on appliance specific behaviour (i.e., use of electric water heaters) and showed that households tend to switch on water heaters three time longer than was necessary, resulting in unnecessary electricity wastage. Two articles recorded changes in specific behavioural actions such as heating and cooling electricity-use behaviour in response to changing seasons (Reade et al., 2016; Berkouwera, 2020). These articles reported a diversity of electricity-use behaviour, ranging from pro-environmental to wasteful actions. Electricity-use data are needed to design accurate predictive models for electricity demand and to design intervention strategies for promoting sustainable use, yet the studies reviewed showed that conclusive judgements cannot be made on electricity-use behaviour across socio-economic gradients.

Determinants of electricity-use behaviour and electricity savings

The articles reviewed on the determinants of behaviour mainly focus on two categories of variables, that is, demographic and psychological factors that impact household electricity use. A sizeable proportion of articles (75%) had a strong focus on the influence of socio-demographic factors such as age, size of family, income, and knowledge of reported electricity-use behaviour (e.g., Louw et al., 2008; Pillay et al., 2014; Zwane et al., 2016; Hori et al., 2013; Ye et al., 2018; Mulamba, 2020; Williams et al., 2020). Thondhlana and Kua (2016) did not find any significant relationship between socio-demographic factors and electricity-use behaviour.

Williams et al. (2020) and Zwane et al. (2016) have shown that older people are more likely to save electricity than younger people, arguing that this is possibly due to older members of households incurring the costs of unsustainable electricity use, or not having young members within their households (who are likely to consume more electricity through day-to-day household activities such as cooking and entertainment). Zwane et al. (2016) and Williams et al. (2020) have also shown that bigger households are more likely to exhibit poor electricity-use behaviour than smaller households due to absolute high electricity demand associated with more people, ownership of electronic gadgets, and difficulty in assigning responsibility for sustainable electricity use. Similarly, Louw et al. (2008), Hori et al. (2013) and Ye et al. (2018) provided evidence that households with more household members, with larger living spaces and many appliances incurred high electricity expenditure.

Sonnenberg and Erasmus (2013) have demonstrated that education and knowledge play a very important role in influencing a household's decision to purchase energy-efficient appliances, consistent with Mulamba (2020) who also found that the more educated household members were, the more they saved electricity. It is argued that making the right decision (buying energy-efficient gadgets) was mediated by awareness about the implications of buying less efficient electronics. Du Preez (2015) has shown that the choice of energy-efficient equipment is influenced by the level of awareness, and people who are generally aware are more likely to purchase energy-efficient equipment. The study also noted that households that had received full information on electricity-saving strategies showed the highest reductions in electricity use, owing to the awareness of using certified household equipment with energy labels, than those households who had not received

such information. These studies highlight the importance of awareness and pro-environmental actions. For example, Nel et al. (2016) showed in a national study of the use of electric water heaters that 25% of the surveyed households did not know the exact length of time needed to heat water, and most of them heated it two to three times longer than was necessary. Overall, the reviewed articles highlighted the importance of socio-demographic factors in shaping electricity behaviour, though Thondhlana and Kua (2016) found that demographic features such as age, gender, education level and household size did not mediate electricity consumption, as found elsewhere (e.g., Hori et al., 2013).

Regarding psychological factors, the reviewed papers showed that values such as openness to change were likely to result in household electricity-saving behaviour attributed to the theoretical construct that having a disposition towards change was likely to result in being receptive to new ideas and experiences, and valuing environmental protection (e.g., Thondhlana and Kua, 2016). Williams et al. (2020) have reported a positive correlation between universalism and pro-environmental electricity-use behaviour, arguing that people who are concerned with nature or care for the welfare of others are highly likely to act in the interest of the environment.

Nel et al. (2016) have shown that convenience is a key determinant of electricity-use behaviour, illustrating how people's willingness to engage in electricity-saving behaviour is determined by how much effort is needed to perform that behaviour. For example, participants who perceived that switching on and off their electric water heaters manually was not easy did not switch them off. Another significant psychological predictor of electricity-use behaviour is attitudes, which measure the favourability of engaging in a particular behaviour (Ajzen, 1991). For example, a case study by Davis and Durbach (2010) on the shift from regular light bulbs to more efficient fluorescent lights shows that attitudes were the central determinant of electricity consumption behaviour. Positive attitudes such as confidence and determination were found to be factors that aided electricity-saving interventions. Negative attitudes, such as doubt and frustration, resulted in non-engagement in electricity conservation. Davis and Durbach (2010) have suggested that an understanding of different attitudes and other preferences for conflicting electricity-related attributes is important in creating models for understanding household electricity consumption.

Overall, the reviewed articles showed a dearth of literature on electricity-use behaviour and its determinants. While the few notable exceptions provided important insights into household electricity-use practices in South Africa, they were insufficient to make conclusive judgements needed to inform strategies for promoting electricity conservation. A notable gap relates to lack of understanding of how electricity-use behaviour and its determinants manifest across the socio-economic gradient. South Africa has marked inequalities among household groups, and it is plausible to argue that the electricity needs and affordability between different income groups are varied (Wolpe and Reddy, 2015; Issock et al., 2017). In South Africa, high-income households consume more electricity than low-income households (Williams et al., 2020). Hence, recent studies have suggested that behavioural interventions should be income-group specific (Issock et al., 2017) because the level of behavioural interventions required for one income group might be different from the other, given different electricity needs and consumption levels. Therefore, an understanding of electricity use by income groups might provide useful insights needed to craft group-specific interventions for promoting electricity conservation. Abrahamse and Steg (2009), Finisterra do Paco and Raposo (2010), and Gray et al. (2011) conducted similar studies in Europe where the emphasis was on how various socio-demographic factors, such as income, contribute to households' direct and indirect electricity-use patterns and savings. The studies also evidenced differences in electricity-use behaviour based on income groups, which supports the need for understanding electricity-use behaviour along an income gradient. Another notable gap in the reviewed literature is on the determinants of household electricity-use behaviour, making it difficult to generalise understanding of the drivers of electricity-use behaviour exhibited by South African households.

Electricity-saving interventions

The reviewed articles covered three types of electricity-saving interventions: technical, behavioural, and economic, but generally, studies on technical interventions were more widespread (73%) than those dedicated to behavioural (23%) and economic (9%) strategies (Figure 2.3). Technical interventions were divided into two main groups, namely technical fixes, and efficiency interventions. Technical fixes relate to infrastructural maintenance and the increase of electricity flow into the national grid to meet the growing electricity demand. For example, the South African Energy Sector Report (2018) has suggested several improvements for increasing

the flow of electricity into the national grid, including diversifying electricity in-flows into the grid. For example, Beute and Delpot (2006) have suggested that improvements to algorithms used to control the hot-water load without interfering or inconveniencing the customer and retrofitting household water heating systems to reduce electricity consumption can reduce electricity demand. Similarly, Longe et al. (2017) have shown the potential of the Device Operation Knowledge - Electricity Usage Plan (DOK-EUP) device in reducing electricity consumption, specifically, demand during peak hours. The device is designed to use algorithms to schedule non-use of shiftable household appliances during peak periods without inconveniencing the consumer. For example, a refrigerator is designed to work 24 hours a day, but the consumer would not be inconvenienced if it was switched off for two hours during peak usage periods. The study observed that this could result in considerable electricity savings and a balance on the national grid, especially considering that about 70% of South African households have refrigerators. The system was tested on other household appliances such as heaters and washing machines, and the results showed that using the DOK-EUP could save up to 25% and 67% of household electricity in winter and summer, respectively. De-Jager et al. (2012) have shown that a ripple relay system designed to shift the heating load of geysers out of peak demand times can minimise pressure on the grid.

Other technical fixes relate to new technologies aimed at steering households towards reduced electricity consumption which could minimise pressure on the grid. For example, the South African Country Report (2005) has advocated for poor households to find cleaner non-grid alternatives for dirty fuels such as coal, through the fire lighting method to reduce air pollution. This method is identified as a cheaper way dirty fuels like coal can be used by households for cooking, which in turn, minimises grid instability, carbon emissions and electricity expenditure. The practice of installing off-grid electricity alternatives to minimise pressure on the grid and to reduce carbon emissions has also been reported in Europe and America since the signing of the Paris Agreement in 2015 (International Energy Agency, 2017). For instance, in the Netherlands, there are Smart Integrated Decentralised Energy (SIDE) system projects where rooftop solar panels, storage batteries and heat pumps have been installed to generate electricity which is distributed among households (Tarbert, 2018). These projects contribute up to 8.6% of the country's electricity production (Tarbert, 2018).

A sizeable proportion (31%) of articles focused on energy efficiency for specific household practices, such as water heating (e.g., De-Jager et al., 2012; Hohne and Numbi, 2018), air conditioning (e.g., Domestic Use of Energy, 2014), heat pumps (e.g., Domestic Use of Energy, 2012), and for specific appliances such as audio and visual gadgets that can consume electricity on standby mode (e.g., Bredekamp, 2006). Bredekamp (2006) carried out an appliance-based experiment to measure the amount of electricity used by audio and visual gadgets when they are on standby mode and has shown that power losses of several household appliances in standby mode ranged between 0.9% and 6.5% of the average national electricity consumption. These studies suggest technical improvements to household appliances which operate on standby mode might avoid unnecessary electricity losses and contribute to grid stability.

Hohne and Numbi's (2018) study on the effects of the installation of efficient water heating systems on electricity consumption showed that Electricity Tankless Water Heaters (ETWH) ensured instant hot water access while consuming less electricity. Unlike the conventional water heating methods, the ETWH is switched on only when hot water is needed, which saves considerable amounts of electricity. Hohne and Numbi (2018) have also endorsed the implementation of the Hybrid Solar/electric storage tank Water Heater (HSHW) which has been designed to use solar energy during the day and then to switch automatically to electricity during the night. This system has been designed to minimise electricity use and costs in cases where hot water is needed both during the day and the night. Hohne and Numbi (2018) suggest that retrofitting conventional water heating methods can make them more energy efficient. These findings are consistent with those of De Jager et al.'s (2012) study on cylindrical water geysers, and suggest that improvements to the technical aspects of water geysers, such as installing dual elements rather than one element, insulating with a blanket, and installing ripple relays can improve their heat retention by 12%. In their experiment, they found that installing two 1.5 kW elements in a geyser saved 13% more electricity per month than installing one 3 kW element.

Nortje (2006) has also highlighted opportunities for Demand Side Management (DSM) initiatives in the residential sector. The paper suggests that the residential sector consumes about 17% of the total grid electricity and contributes up to 35% to the maximum electricity demand, which is quite substantial. Hence DSM strategies, such as energy-efficient lighting, home insulation, hot water

piping and the use of geysers in the residential sector can provide an opportunity for substantial electricity savings. A study by Setlhaolo and Xia (2016) sought to combine DSM strategies, such as appliance scheduling, with other complementary power sources, such as photovoltaic devices and battery storage systems. In the study they reported that these technical interventions had the capacity to reduce electricity consumption by about 14%, amounting to about 15% of electricity cost savings.

Behavioural interventions

Findings showed that very few articles (23%) examined behavioural interventions for promoting electricity savings. Some articles examined the effectiveness of behavioural interventions by applying different treatments (provision of electricity-saving information, discussions, and feedback on performance) (e.g., Du Preez, 2015; Nel et al., 2016; Thondhlana and Kua, 2016; Issock et al., 2017). The studies showed substantial electricity savings, ranging from 2% to 5%, for households who received the full suite of intervention measures. There was also a focus on psychological interventions. Du Preez (2015) has shown that awareness and knowledge of electricity-saving interventions yielded electricity-saving behaviour. Treatment groups that received sufficient information on electricity-saving tips and the importance of efficient lighting through engaged discussions showed more electricity reduction than groups that received partial treatment (those who received information only in the form of pamphlets) and the control (those that were not subjected to any treatment). A similar study by Thondhlana and Kua (2016) among low-income households showed that households that were provided with electricity-saving information in the form of pamphlets and stickers, combined with performance feedback, yielded more electricity savings of 24.50 kWh/month than households that did not receive information. These studies lend weight to the importance of behavioural interventions in promoting electricity conservation.

The Residential Sector Report (2012) also highlights the importance of public awareness as a very important intervention towards achieving an energy-sustainable South Africa. For example, the Department of Energy endorsed awareness campaigns such as the 49 Million Campaign launched in March 2011. This campaign was conducted by the national energy utility, Eskom, and the government and appealed to South African citizens, including households and children, to use

electricity sparingly. The report suggested that such campaigns have the capacity to influence behaviour change and ultimately result in electricity and financial savings. Similarly, Davis and Durbach (2013) have suggested that, if households are informed of the various ways of saving electricity (e.g., the amount of electricity needed to boil water, boiling enough water as needed), they are likely to save electricity. Hence the paper also emphasises the importance of awareness campaigns as an essential intervention for sustainable household electricity consumption.

Concerning market-based behavioural nudges, Nel et al. (2016) have found that behaviour change in the use of water heaters could be highly motivated through financial incentives. For example, they discovered that time-based electricity tariffs (commonly used in the commercial and industrial sector) can be a very important intervention to decrease the amount of electricity used for water heating during peak periods and so minimise pressure on the grid. The methods work through differential pricing between peak and non-peak periods to discourage the use of electricity during peak periods. Moreover, financial incentives also seemed to be very powerful in determining the shift of consumption to non-peak periods. For instance, the study found that about 82% of the surveyed households were willing to defer their use of water heaters to inconvenient times, on condition they were compensated financially. Similarly, Du Preez (2015) has shown that financial incentives are influential in determining the adoption of certain electricity-saving behaviour by households but warns that economic interventions are temporary, arguing that behaviour motivated by financial incentives is only exhibited when the incentives are being administered and they tend to disappear as soon as the incentives stop.

Nyatsanza (2010) has also shown that economic interventions such as ‘price hikes’ have the ability to save up to 15% of electricity consumed by households, but this can drop with rebound effects associated with such interventions. Nyatsanza (2010) further cautions that most of the intervention targets in South Africa are set based on the results from First World countries like Germany and such interventions might not reap the same results locally. Therefore, intervention drafters need to be cognisant of contextual differences and should also leave a gap for rebound effects. The study also highlights the importance of coupling interventions. For example, it compared the effectiveness of energy efficiency and price interventions versus energy efficiency and awareness

and found that energy efficiency and price interventions had the capacity to save 11% of electricity whereas energy efficiency and awareness could save about 17% of electricity.

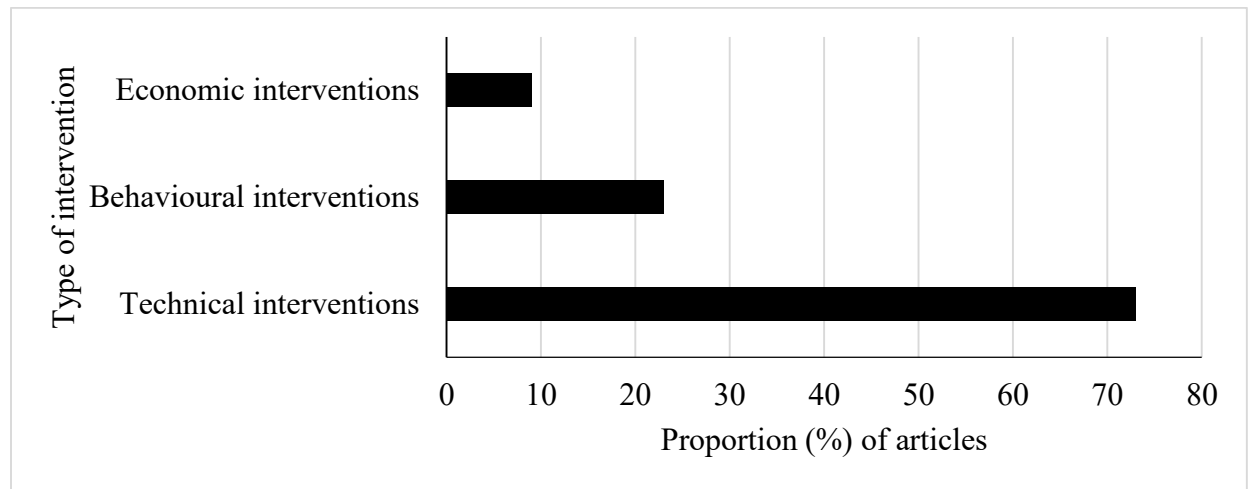


Figure 2.3 Types of electricity-saving interventions

2.4. Discussion

The increase in literature from the period after 2011 may suggest that electricity-use practices at household level is an area that is gaining traction in South Africa. These studies are a promising step towards developing pathways to sustainability transition in the household sector. However, relative to developed contexts (for example the EU and USA), the literature on household electricity-use behaviour and the determinants of behaviour is still very limited, making it difficult to sufficiently inform both policy and practice for promoting household electricity conservation via behavioural interventions.

Concerning interventions, the results show that relatively more research is devoted to technical fixes than behavioural strategies. Technical interventions present an opportunity to support electricity conservation in the residential sector. Studies on technical interventions are important in advancing our understanding of the potential of the various types of technical interventions for reducing electricity use. However, although technical interventions are important in reducing electricity wastage, they do not address wasteful electricity-use habits (Langevin et al., 2013), which is a cause for concern in sustainability debates. Further, electricity efficiency gains through technical interventions can be offset by consumption growth (Midden et al., 2007) related to

ownership of household electronic equipment. Another point to consider is that technical interventions often require huge capital investments which might be a constraint on low-income households as they consider their priorities. The articles reviewed neither discuss nor suggest how technical interventions can be made available to households at a minimum cost. In addition, considering the dispersed nature of electricity use in the residential sector, it is more difficult to regulate using technical interventions in households than in the industrial sector, which is relatively centralised (Wubbeke and Heroth, 2014). Further, investment in electricity infrastructure such as power-generating plants might be problematic for economic and environmental reasons. For example, the South African power utility, Eskom, is struggling financially and needs government bailout, hence it is unable to build more or maintain existing power stations (Department of Energy South Africa, 2019). Thus, technical interventions might not be suited to contexts characterised by an economy performing poorly and lacking the technical expertise (Council of Scientific and Industrial Research, 2020). Further, investment in more coal-powered plants for electricity generation is inconsistent with the principles of sustainability transition debates, as coal-powered electricity is one of the reasons there are calls for investment in behavioural interventions for reducing electricity consumption.

The limited literature on behavioural interventions makes it difficult to draw useful conclusions on the effectiveness of behavioural interventions and determinants of success. Several questions remain unanswered: What is the influence of interventions among different income groups or on specific behavioural actions? Can the interventions yield sustained pro-environmental behaviour? Answers to such questions can provide a greater understanding into electricity users' specific characteristics and behavioural patterns as a basis for the application of contextually relevant interventions. Therefore, more research work that explores the effectiveness and persistent effect of behavioural interventions in promoting household electricity savings is needed to develop deeper insights on the subject and on investment in such interventions. Another key gap in the literature related to behavioural interventions relates to studies on households' knowledge about energy efficiency labelling. Despite the dominance of literature on energy efficiency, there is no clear picture of what factors shape people's decisions when purchasing household electronic gadgets. The reviewed articles mainly highlight the effectiveness of using appliances with energy labels, but without attempts to evaluate the state of knowledge and awareness about people's

choices. More work which sensitises people to the importance of energy efficiency, and which evaluates the state of knowledge of energy-efficiency interventions and labelling is needed.

Further, there is limited work premised on the involvement of electricity users in co-designing the electricity-saving interventions, though these approaches are increasingly receiving attention (Ambole et al., 2019; Thondhlana et al., 2021). Ambole et al. (2019) and Du Plessis (2015) have discussed the value of co-designing interventions as a basis for transition to sustainable electricity consumption. The central argument is that electricity use is a complex subject that requires collaborative processes and the involvement of other stakeholders in co-production of knowledge and in crafting of interventions. Thus, there is a need for more research on how partnerships can be used to collectively formulate sustainability challenges and co-design interventions that are relevant to contextual realities as suggested by others (e.g., Thondhlana et al., 2021).

2.5 Conclusion

Human behaviour is a complex phenomenon but understanding it can be a useful tool for promoting household electricity conservation which can yield economic gains to the users and environmental benefits from reduced carbon emissions. The reviewed literature on household electricity use in South Africa provides useful insights on the topic but these cannot be generalised. This review shows that, apart from a few recent exceptions, there is a general lack of literature on households' electricity-use behaviour, the determinants of such behaviour and behavioural interventions to promote electricity conservation. The available literature shows mixed outcomes and does not provide a full picture of household electricity-use behaviour and the factors influencing it across an income gradient. Therefore, future research should focus on examining household electricity-use practices and the determinants of behaviour in different socio-economic contexts to account for the influence of socio-economic disparities. Further, greater research emphasis should be placed on examining the effects of electricity-saving interventions on consumption. While recent technological advances mean that huge gains have been made in saving electricity via production of energy-efficient technologies and retrofitting, low-income household groups might not be able to afford improved technologies owing to high costs. This means the sustainability transition debate might not consider the perspectives of low-income groups. Thus, there is a need for research to focus on the effects of behavioural interventions in promoting

household electricity conservation, especially among the poor. Given the benefits of technical interventions, we suggest that future research should also focus on the combined effects of technical and behavioural interventions, which we believe might yield more electricity conservation gains than relying on one form of intervention. Lastly, we believe that prescriptive approaches that merely transfer electricity-saving interventions from one context to the other will not succeed, owing to contextual differences. Rather, inclusive approaches that allow the participation of stakeholders with an interest on electricity conservation to design electricity-saving interventions, for example co-designing, might help align research goals and the realities, needs and priorities of local users. Thus, key to promoting electricity conservation should be extensive research on co-designed intervention strategies.

Chapter 3: Reported behavioural patterns of electricity use among low-income households in Makhanda, South Africa

Abstract

Households consume up to 20% of overall electricity consumption globally; hence, they are important role players in efforts towards promoting sustainable consumption. Research on electricity-use behaviour is important for informing intervention strategies; however, relative to developed countries, research on this subject is lacking in developing countries where electricity-access is limited. In South Africa, electricity-use behaviour among poor neighbourhoods remains little studied and understood. This study was carried out among low-income households in Makhanda, South Africa, characterised by high poverty and unemployment rates, low education levels, and limited access to basic services. Using a self-reporting approach, electricity-use behaviour of low-income households was assessed against a list of common household electricity-use actions. A survey of 297 households was conducted. The findings show mixed results, with households reporting both good electricity-use behaviour (e.g., cooling down hot food before refrigeration and using washing machines on full load) and wasteful actions (e.g., leaving appliances on standby). Our results show that electricity-use behaviour was influenced by socio-psychological values including universalism, benevolence, hedonism, and power. Some of the reported electricity behavioural patterns are consistent with those previously reported among high-income households. The theoretical and practical implications of these results are discussed.

Keywords: low-affluent households; electricity consumption; reported behaviour; interventions

3.1 Introduction

Globally, households consume a notable amount of electricity, with estimates suggesting that the residential sector accounts for up to 20% of overall electricity consumption (Ivanova et al., 2016). Electricity is a basic social and economic need, but unsustainable use has several socio-economic and environmental repercussions (Ivanova et al., 2016; International Energy Agency, 2020). The socio-economic and environmental costs of unsustainable electricity consumption are quite considerable, and can be seen in carbon dioxide emissions (Azevedo et al., 2018), grid instabilities (Alborg et al., 2015), and energy poverty (González-Eguino, 2015; Frederiks et al., 2015; Nel et al., 2016). Government authorities and electricity managers from fossil-based economies, such as

South Africa, are therefore faced with a challenge of finding alternative pathways for promoting sustainable electricity consumption to reduce carbon emissions and ensure stable electricity supply (United Nations Environmental Program, 2019).

Similar to global trends, the South African residential sector consumes more than 20% of the total national electricity usage, thereby making it a major carbon emitter (Department of Energy South Africa, 2019) and an important sector when considering efforts for promoting transition to sustainable electricity use. Consistent with major challenges facing the emergent BRICS economies (Brazil, Russia, India, China, and South Africa), the country also faces a seemingly double-sided challenge of simultaneously providing sufficient electricity and mitigating the negative effects of greenhouse emissions (Azevedo et al., 2018). The country is among the top 20 greenhouse gas emitters globally (Timperley and McSweeney, 2018). A recent report by the South African electricity public utility company, Eskom, highlights that its power-generating plants produce high levels of carbon emissions and consume a lot of water (Eskom, 2020), and this is also linked to Eskom's aging infrastructure. At the local level, municipalities are in huge debts amounting to about ZAR 28 billion (US\$1.87 billion) and are at risk of being disconnected from the national grid by Eskom (Department of Energy South Africa, 2019; Eskom, 2020). Despite the high rate (about 90%) of household access to electricity, the country remains energy insecure and a high proportion of households are energy poor (Mbewe, 2018). The country is often burdened by recurrent power cuts, which disrupt service delivery and social lives (Eskom, 2020; Esterhuizen, 2019). A recent Eskom report shows that the company is in a financial crisis and urgently needs a government bailout of more than ZAR 50 billion (US\$3 billion) in 2021 to maintain its operations—an amount that is quite huge, given the struggling economy (Eskom, 2020).

Considering the substantial amount of electricity consumed by the household sector, households are an important target for sustainable consumption debates and practice. Designing pathways towards sustainable electricity consumption at the household level can be achieved by an understanding of household electricity-use behaviour (Kua and Wong, 2012; Steg et al., 2015). A focus on reported behaviour for mapping sustainable electricity-use pathways is important for several reasons. First, the benefits of sustainable electricity use accrue directly to the user because

of reduced electricity bills (International Energy Agency, 2020). Second, technical interventions such as retrofitting efficient equipment and construction of more infrastructure cannot address unsustainable consumption, and hence, are bound to be short-term solutions considering the predicted growth of most developing economies (Vlad et al., 2011). In South Africa, recurrent imbalances between electricity supply and demand, and the resultant power cuts, provide sufficient evidence that technical interventions may be useful but insufficient to address the country's electricity instability (Eskom, 2020). Third and related to this, the expenses of retrofitting and building new infrastructure are quite substantial and beyond the reach of financially strapped governments and power utilities, as noted earlier, hence the need for investing in behavioural change interventions. Fourth, although regulations such as electricity-efficiency labelling can result in the production of energy-efficient gadgets as seen in the USA, European Union, and Australia (European Union, 2020), many developing country households may not be able to afford these gadgets, or if they can, the propensity to buy more electronic appliances with increasing disposable income may result in consumption overtaking efficiency (Midden et al., 2007).

Therefore, behavioural change is arguably a cheaper and more sustainable way to achieve electricity conservation (Abrahamse et al., 2005; Abrahamse and Steg, 2009) and, in turn, address grid instability and energy poverty. Behaviour change has low implementation costs (Abrahamse et al., 2005), can benefit users directly, is long-term, and can reduce municipal electricity bills, which means financial savings can be used on other service delivery issues (Caballero et al., 2020). However, there is still limited work on residential electricity consumption in South Africa apart from a few noteworthy exceptions (Williams et al., 2020; Thondhlana and Kua, 2016). Existing research on household electricity is useful but has limited scope with generic outcomes, which does not provide a complete picture of sustainable electricity-consumption patterns. For example, examining electricity-use behaviour among high income households only (Williams et al., 2020) is not comprehensive given that most people in developing countries reside in low-income areas, thus the need for studies in these areas. Other works examine behaviour on specific gadgets only, such as the use of electric heaters (Nel et al., 2016) or home appliances with standby functions including satellite boxes and stereos (Shuma-Iwisi and Gibbon, 2009). The dispersed literature on household electricity-use behaviour makes it difficult to understand and develop useful frameworks for encouraging sustainable electricity use. Consequently, not much investment has

been directed towards the promotion of sustainable electricity use at the household level (Marais, 2019), despite South Africa's intensive electricity use and huge environmental footprint. The diversity of income groups in South Africa (low, middle, and high) requires an understanding of electricity-use behaviour from different socio-economic groupings using similar measures.

Understanding the electricity-use behaviour patterns of low-income households has both scholarly and practical value. First, it can be compared with similar work among high-income households, which could allow detection of behavioural trends and generalisation of inferences, bearing in mind that different sets of conclusions can be drawn, and corresponding policy recommendations crafted. Second, a focus on low-income groups can allow identification of problematic behavioural patterns, which can be used to inform and support targeted interventions and policies for transition to sustainable electricity-use behaviour. Third, from a moral standpoint, user-driven behaviour change interventions can contribute to a reduction in energy poverty, and financial savings from sustainable electricity consumption, which can improve household welfare. This is particularly important in South Africa, where energy poverty is widespread, with nearly half (47%) of the population considered to be energy poor (lack access to or cannot afford basic energy services) (Department of Energy South Africa, 2019). A previous study Kambule et al. (2019) found that low-income households in Soweto township in Johannesburg used more than 66% of their income on electricity purchase, which is quite substantial given that they earn low incomes. More often than not, poor households resort to unclean and unsafe alternative sources of energy such as kerosene and fuelwood (Musango, 2014; Israel-Akinbo and Fraser, 2018). Thus, crafting of effective options for ensuring energy security and household welfare improvement should consider the electricity-use behavioural patterns of low-income households.

3.1.1 Understanding behaviour

Wasteful electricity use practices in the household can be attributed to human behaviour (Steg et al., 2015; Steg, 2008). Household daily electricity-consumption practices have a direct impact on electricity demand (Laicane et al., 2015); hence, wasteful behaviours pose serious implications for both the household financial budget and the national grid (Eskom, 2020; Caballero et al., 2020). Unsustainable electricity-use practices can result in energy poverty (González-Eguino, 2015; Mbewe, 2018) as a result of high electricity expenditures relative to income (Mbewe, 2018), as

well as power cuts when electricity demand outstrips electricity supply, and can adversely impact the environment due to carbon emissions (Eskom, 2020). Hence, encouraging sustainable electricity-use behaviour at household level can minimise these adverse impacts (Kua and Wong, 2012). For example, switching off the lights in unoccupied rooms or turning off the geyser when not in use can result in substantial electricity savings (Meyers et al., 2010). Such electricity-use actions need to be repeated until they become habits.

Habits are defined by Nilsen et al. (2012) as actions (substrates of behaviour) that are repeated and internalised until they become involuntary and largely enacted without awareness or decisive thinking. Daily habitual electricity-use practices such as leaving appliances on standby mode and leaving fans and lights on in unoccupied rooms can result in nescient power losses. According to Mtutu and Thondhlana (2016), electricity users are generally reluctant to completely shut down certain appliances such as computers, satellite boxes, and stereos when they are not in use. This is partly due to forgetfulness, lack of awareness, laziness, unwillingness to compromise convenience, and the need for personal comfort (Thondhlana and Hlatshwayo, 2018). However, leaving appliances on standby mode results in “vampire losses” because appliances consume electricity when they are not in use (Gerber et al., 2019; Olatunji et al., 2019). The literature suggests that standby electricity consumption can account for a significant proportion of household electricity consumption ranging from as low as 4% (Sahin and Koskal, 2014) to as high as 40% (Olatunji et al., 2019).

Several countries in the European Union have come up with several electricity efficiency policies (European Union, 2020). However, with nearly half of the South African population considered poor and residing in low-income areas (Statistics South Africa, 2017), most poor households might not be able to afford electricity-efficient gadgets. Moreover, while technical interventions such as improving the efficiency of electronic gadgets are useful, they do not address wasteful electricity-use behaviours (Langevin et al., 2013). This therefore calls for research in low-income areas where several factors such as use of old inefficient appliances (Kambule et al., 2019), low electricity price (Department of Energy South Africa, 2019), lack of awareness on electricity-saving tips and wasteful use practices (Williams et al., 2020), and illegally connected backyard dwellings (Laicane et al., 2015) are at play and could shape electricity-use behaviour.

3.1.2 Determinants of behaviour

There are several factors that contribute to environmentally relevant behaviour, and by extension, these factors can determine the successes and longevity of behavioural intervention programmes (Abrahamse and Steg, 2009). Amongst these are socio-demographic factors, personal values that individuals hold, and situational factors (Kua and Wong, 2012).

Socio-demographic factors

Studies suggest that socio-demographic factors including gender, income, age, and education play a significant role in determining individual behaviour (Barr, 2007; Abrahamse and Steg, 2009; Trotta, 2018). Positive associations have been found between environmentally friendly behaviour and high levels of education and income (Trotta, 2018). A case study of household waste management in the UK (Barr, 2007) showed that females, highly educated individuals, and those who are elderly often act pro-environmentally. Concerning age, a study by Trotta (2018) in the UK found out that households occupied by age groups from 25 years to 65 years had up to 55% likelihood of engaging in electricity-efficient behaviour as compared to households occupied by people who are 24 years and below, who had less than 13% chance of doing so. These observations support the social class hypothesis, which states that people who receive a high income and are highly educated are more likely to exhibit environmentally friendly behaviour than those with low education and income (Trotta, 2018). However, in Williams et al. (2020) wasteful electricity-use practices were shown among high-income households. Further, in Lindén et al. (2006) electricity consumption by elderly people was found to be more intensive as compared to younger people due to the high amount of time they spend indoors and the intensive use of heating appliances. This shows that the influence of socio-demographic factors on electricity consumption is not absolute and linear, but rather complex and context-specific.

Values

Values are desirable trans-situational goals that work as guidelines for people's behaviour in social settings (Schwartz, 1994). Personal values such as quality of life, comfort, and effort are major determinants of attitudes and behavioural choices among individuals and can assist in determining the probability of a person to act in the interest of the environment (De Groot and Steg, 2007). A comprehensive understanding of personal value factors can be understood from measuring the level of importance given to the 22 Quality of Life (QoL) factors suggested by Poortinga et al.

(2004). These value factors can be further summarised and classified into ten domains, which are universalism, stimulation, hedonism, achievement, self-direction, security, power, benevolence, conformity, and traditionalism (Poortinga et al., 2004). These factors can be further categorised into two main dimensions. The first dimension is openness to change versus conservatism, which differentiates values that stress independence (e.g., stimulation and self-direction) from values that emphasise conservatism (e.g., traditionalism and conformity) (Schwartz, 1994). The second dimension differentiates self-transcendent values (e.g., altruistic values such as benevolence and universalism) from self-enhancement values (e.g., egoistic value factors such as power and self-enhancement value factors such as security) (Schwartz, 1994; De Groot and Steg, 2004; Poortinga et al., 2004). (Appendix 3A)

It is assumed that openness to change can lead to pro-environmental behaviour because people with such attributes tend to receive new ideas and environmentally friendly information more easily than those who have conservative dispositions and self-enhancement values (Frederiks et al., 2015). Conservative people have a lower probability of engaging into pro-environmental behaviour because they like maintaining existing routines and are less likely to buy into new behaviours (Schwartz, 1994). A study conducted by Williams et al. (2020) found out that altruistic people are more likely to save electricity owing to their openness to new ways of doing things and their concern about protecting the environment than those who hold self-enhancement and conservatism values. However, in Mtutu and Thondhlana (2016), it was found that most personal values were not associated with environment-friendly behaviour, and the few exceptions yielded very weak relationships.

Within this context, this study aims to examine the reported electricity-use behaviour among low-income households in Makhandla, in the Eastern Cape province of South Africa. Given that some work has been conducted in high-income households within big cities of South Africa, we aimed to contribute knowledge regarding electricity-use behaviour among low-income households in a small town. Such information can help to identify trends for informing behavioural interventions that can contribute towards electricity conservation. We acknowledge that a more direct approach, such as comparing household electricity-use behaviour between different income groups (low, medium, and high) could have been more robust; however, our aim was to contribute knowledge

from low-income households as part of a broader transdisciplinary project on promoting electricity conservation among low-income households. The following three research questions guided the research:

- What is the reported electricity-use behaviour?
- What are the determinants of electricity-use behaviour?
- What do the findings mean for inferences on pro-environmental behaviour, and practical implications for local- level transition to sustainable electricity use?

The study hypothesises that (i) socio-economic factors such as gender, age, income, and education are more likely to have a positive influence on electricity-use behaviour, and (ii) people with self-transcendent values such as openness to change and altruism are more likely to save electricity than those with self-enhancement values. These hypotheses are consistent with previous studies examining electricity-use behaviour (Williams et al., 2020); however, in this study we aim to test them in low-income households where the socio-economic context is different. The paper is structured as follows: Section 3.2 focuses on the materials and methods, whilst results and discussions are presented in Section 3.3, and conclusions are presented in Section 3.4.

3.2 Materials and Methods

3.2.1 Study area

The research was conducted among low-income households in Makhanda (33°18'33.0" S and 26°31'36.0" E), located in the Eastern Cape province of South Africa (Figure 3.1). The estimated population of Makhanda is about 70,000 (Statistics South Africa, 2011). Consistent with most towns in South Africa, Makhanda's mostly poor population has increased since the country's transition from apartheid to democratic rule in 1994. The increasing population size is attributed to an influx of people from surrounding communal black homelands into the town (Freund, 2007).

The Eastern Cape province is the poorest in South Africa, characterised by low levels of education and a high unemployment rate of about 33% (Statistics South Africa, 2011). It is estimated that only 15% of the total population has tertiary education, 5.5% are regarded as totally illiterate, while only about a quarter (24%) has National Senior Certificate (the highest qualification before tertiary level studies) (Statistics South Africa, 2011). Due to the high unemployment levels, a significant proportion (41%) of households receive government social grants, with recipients of social grants

being higher for low-income than high-income households (Statistics South Africa, 2011). Like other South African cities, Makhanda's urban and geographical arrangement is characterised by apartheid spatial settings (Freund, 2007). The Western side is made up of high-income households while the Eastern side accommodates low-income households. The Eastern side is generally characterised by low education levels, high unemployment levels, and small homesteads and houses. Houses consist of three types, namely, privately built blocks, state-built houses, and informal houses (locally known as shacks), made from an assortment of scrap metal, iron sheets, and wood and dagga. The low-income groups generally earn below ZAR 2500.00 (approximately \$167) per month, which reflects a low social status, while the middle- and the high-income earn double and four times this amount, respectively (Statistics South Africa, 2011). Because of the above-mentioned low education levels, high unemployment, and a high population of low-income earners, Makhanda is ideal for examining the key questions posed in this study.



Figure 3.1 Location of Makhanda in Eastern Cape province of South Africa.

3.2.2 Sampling and data collection

This study is part of the broader two-year Leading Integrated Research for Agenda 2030 in Africa (LIRA 2030) funded project. Ethics approval for this project was granted by the Rhodes University

Ethics Committee (Review Reference No. 2019-0720-730). LIRA 2030 is a 5-year research programme that aims to support the production of “high-quality, inter- and transdisciplinary, solutions-oriented research on global sustainability by early career scientists in Africa”. The sampling strategy was informed by the need to recruit participants willing to be part of a two-year research project. The households were selected via convenience sampling using social clusters. In convenience sampling, the research selects participants who are conveniently located and those who are willing to cooperate (Emerson, 2015). Hence, this approach was employed in this study as it upholds volitional choice, that is, voluntary participation of participants. Although findings are not generalisable (Emerson, 2015), the intention of this study was not to make generalisations but to acquire insights that can be transferable in our understanding of a complex and subjective research question of electricity consumption behavioural patterns. Data collection took place between October and November 2019, as part of the baseline data in the broader above-mentioned LIRA 2030 project.

The research targeted household heads and, in their absence, the eldest adult member of the family with a fair understanding of how electricity is used in their respective household. In total, 297 households selected from Tentyi, Joza, Pumlanzi, Vukani, and Fingo suburbs participated in the study. A structured questionnaire designed to obtain sociodemographic information, personal values, and daily self-reported electricity-consumption actions was used for data collection. The questionnaire was pretested for errors, clarity, and consistency among 35 households. The study recruited local volunteers (electricity champions) to help in the data collection process. These volunteers were pre-trained at Rhodes University before data collection, to ensure a general understanding of the nature of the research, and how to interpret responses and record them properly. There were no expected variations in responses between data collectors as all questions were closed-ended, and the respondents chose from a given set of answers.

Measures

- Socio-demographic variables

The questionnaire captured socio-demographic information of the respondents and their household structures including age, gender, household size, education level, social grants status, employment,

household size, number of rooms in the house, whether they are recipients of government free electricity, and ownership of appliances.

- Electricity use behaviour

Electricity use behaviour was measured from a set of 20 electricity-use actions (Appendix 3B) related to the use of household appliances including entertainment gadgets (e.g., computers, desktops, and televisions) and kitchen appliances (e.g., refrigerators, stoves, and microwaves). These electricity-use actions were drawn from previous studies in South Africa (Thondhlana and Kua, 2016; Williams et al., 2020) and represent common areas of electricity use in many households. The questions asked how often the respondents engaged in given actions. For example, “How often do you use matching pot sizes and hot plates on a stove?” Electricity-use behaviour was then scored on a five-point Likert scale (1 = never; 2 = rarely; 3 = sometimes; 4 = usually; 5 = always). Responses were computed from the 20 electricity-use actions, with average scores close to 1 and 5 representing poor and good electricity behaviour, respectively.

- Values

Participants were asked to self-report the degree of importance they attached to a list of personal value orientations (22 QoL factors) on a five-point Likert scale (1 = unimportant; 2 = less important; 3 = important; 4 = very important; 5 = critical), following Poortinga et al. (2004). The QoL factors were further classified into nine value domains, which are universalism, self-direction, benevolence, security, hedonism, stimulation, power, achievement, and traditionalism. These were further divided into four high-order values, namely, self-transcendence, openness to change, self-enhancement, and conservation, following Williams et al. (2020). Finally, individual scores were combined under each domain with average scores close to 1 and 5 representing a low and high disposition to the particular value orientation.

3.2.3 Data analyses

Data were analysed through STATISTICA (Version 13). Socio-demographic data were summarised in tables using descriptive statistics. Mean scores for each electricity-use action were calculated to indicate electricity-consumption behaviour. Frequency of electricity-use behaviour was indicated through modal responses. Action scores for appliances owned by less than 10% of

the sample were excluded in the analysis as this information cannot provide useful insights into potential interventions applicable to the whole community. Given that data were coded, non-parametric tests were used for analytical statistics. Differences in mean behaviour scores between males and females were tested through a Mann–Whitney test. A Spearman’s correlation analysis was performed to find out the direction and strength of relationships between electricity-use behaviour, and socio-demographic and personal value factors.

3.3 Results and Discussions

3.3.1 Socio-demographic profile of the participants and their households

Of all the participants, there were more males (65%) than females (35%) (Table 3.1), and the mean age for all participants was 47 ± 17 years. The average household size for the research sample was 4.3 ± 2 , with adults (18 to +65 years) constituting 67% of the targeted population. Participants were characterised by low levels of education, with about 20% having no education at all, 14% with primary education only, 47% with secondary education, and only 19% having attained either a diploma or a degree. Less than half (47%) of the participants were formally employed, and out of these just above half (56%) received a monthly income of less than ZAR 3500 (US\$233), about 43% ranged between ZAR 3500 and ZAR 10,000 (US\$233–US\$667), and only 1% had income between ZAR 10,000 (US\$667) and ZAR 30,000 (US\$2000). About 79% of all the participant households received government social grants, which suggests limited employment opportunities and high poverty levels. About 75% lived in their own formal building structures, 21% in government Reconstruction and Development Programme houses (RDPs), and about 4% in informal building structures. Roughly 64% of the households had separate household units within their homesteads, and out of these, only 35% had separate electricity meters for different units. A sizeable proportion (40%) of the households received monthly Free Basic Electricity (50 kWh) from the government, which is given to poor households. Apart from electricity, households used multiple sources of energy with more than half (51%) using gas, 41% (paraffin), 7% (firewood), and 1% (solar).

Table 3.1 Socio-demographic characteristics of participants and households.

Variable	Values
Gender (%) of household head	
Female	35%
Male	65%
% household heads	53%
Mean age of respondent (years)	47 (± 17)
Mean household size	4.3 (± 2)
Below 5 yrs	9%
6–17 yrs	24%
18–35 yrs	29%
35–65 yrs	29%
+65 yrs	9%
Education of household head (%)	
No education	20%
Primary	14%
Secondary	47%
Tertiary	19%
% of household heads employed	46%
Number of members employed/household	0.97
% of households receiving social grants	79%
Income bracket (ZAR)	
<3500	56%
3500–10,000	43%
10,001–30,000	1%
>30,000	-
% of households receiving free basis electricity	40.5%
Alternative electricity	
Gas	51%
Paraffin	41%
Firewood	7%
Solar	1%
Household description	
Own built formal	75%
Reconstruction and Development Programme houses	21%
Informal/Shack	4%
% of homesteads with separate housing units at the homestead	64%
% households with separate meters for different units	35%

The results show that a sizable proportion of the population under study receive social grants, consistent with poor urban communities in South Africa. Social grants are given to people who live below the country's poverty line which is ZAR 810 per person (US\$53.32) (Statistics South Africa, 2011). Social grants are an initiative under the Social Security in South Africa, which was established in 1994 with the goal of alleviating poverty and improving social lives of marginalised communities (Statistics South Africa, 2011). The substantial number of households that receives Free Basic Electricity (FBE) shows that a considerable number of the participants are poor. Free Basic Electricity is an initiative that was launched by the South African Government in 2003, with the main goal of supporting poor households in meeting their basic electricity needs (Musango, 2014). The number of participants in RDPs, and those who use paraffin as an alternative form of energy also shows that a sizeable proportion of the community is poor and cannot afford cleaner forms of energy. These results are consistent with findings elsewhere (Musango, 2014), which showed that paraffin is one of the widely used alternatives to electricity in poor communities.

3.3.2 Ownership of appliances and lighting

More than 75% of the participant households possessed common electric kitchen appliances such as kettles, refrigerators, stoves, and microwaves, and entertainment and communication gadgets such as TVs, satellite boxes, stereos, and cell phones (Table 3.2). Slightly more than half of the households had computers and washing machines while less than half had electric geysers, water heating elements, fans, electric heaters, electric blankets, vacuum cleaners, tumble dryers, air conditioners, and dishwashers. About 80% used LED lighting, 3% used incandescent lighting and/or florescent, and 10% used more than one form of lighting. The remaining 4% did not know the type of lighting they used.

Table 3.2 Ownership of appliances by households.

Appliance	% Households
Kitchen appliances	
Electric kettle/jug	99
Refrigerator	95
Electric stove	88

Microwave	79
Dishwasher	2
Washing machine	63
Entertainment and communication	
TV	96
Satellite boxes	96
Stereo	96
Cell phone	96
Computer (desktop/laptop)	52
Other appliances	
Electric cylindrical water heater	33
Element water heater	32
Fan	26
Electric heater	19
Electric blanket	10
Vacuum cleaner	7
Tumble dryer	6
Air conditioner	4

3.3.3 Reported electricity-use behaviour

Participants were asked to indicate their frequency of engagement in several electricity-use actions, and the results are presented in Appendix 3B. Good electricity use-behaviour reported, as illustrated by mean scores of at least 4 and respondents reporting usually or always practicing an action, include cooling down hot food before packing it in a refrigerator, covering liquids when storing in the refrigerator, making use of daylight instead of lights during the day, and turning off lights in empty rooms. Out of all the actions that were usually or always practiced, at least half of the respondents reported so, which is illustrative of environmentally friendly behaviour. A modal response of “always” was reported for actions such as turning off digital microwaves completely, matching pot sizes and hot plates on stoves, unplugging phone chargers, and turning off cylindrical water heaters (geysers), but by less than half of the respondents showing both good and wasteful electricity-use practices. Low scores (<3.5) were recorded for actions such as adjusting refrigerator power settings according to weather, switching off the refrigerator when it is empty, defrosting refrigerators without automatic settings, and turning off appliances completely instead of leaving them on standby, with most respondents reporting ‘Never’ or ‘Sometimes’ doing these actions. About 43% of participants ‘Sometimes’ defrost the refrigerator without an automatic setting, about

53% ‘Sometimes’ overload their refrigerators, 71% ‘Never’ adjust refrigerator settings according to weather conditions, 48% ‘Never’ switch off their refrigerators when they are empty, 83% ‘Never’ use task lighting for activities that need minimum lighting, and 33% ‘Never’ turn off appliances but rather leave them on standby. Consistent with Williams et al. (2020), the results from this study show that there are elements of positive behaviour among low-income households. For example, people always cooled down hot food before storing it in the refrigerator and always turned off lights in empty rooms. This shows that even poor people have instances where they act in the interests of the environment, results which are contrary to conventional knowledge (Liere and Dunlap, 1980). A possible explanation is that these electricity-use actions are easy for them to do, or they are more informed about the benefits of practising them than the knowledge they might have on standby electricity losses.

The findings also highlight evidence of poor environmental behaviour related to standby electricity loss. This is consistent with previous studies in low-income households (Thondhlana and Kua, 2016), in high-income households (Williams et al., 2020), and in a university setting (Bulunga and Thondhlana, 2018), where wasteful electricity-use practices were common including not switching off appliances completely when they are not needed.

Comparison of the reported electricity-use behaviour with high-income households (Williams et al., 2020) shows both similarities and considerable differences. Both low-income and high-income households reported good behavioural patterns including keeping windows and doors closed when heater is on, cooling down hot food before storing in refrigerator, making use of daylight instead of lights during the day, and turning lights off in empty rooms. However, notable differences were noted, with low-income households, albeit less than half, reporting good electricity-use behaviour such as unplugging phone/iPad chargers after use, turning off geysers when not in use, and defrosting refrigerators compared to high-income households (Williams et al., 2020). However, our study findings show poor electricity-use behaviour among low-income households including never turning off home appliances completely when not in use. This suggests that wasteful electricity-use practices are prevalent among both low and high-income households.

3.3.4 Relationship between Pro-Environmental Behaviour (PEB) and socio-demographic factors

A Spearman correlation coefficient was performed to ascertain the relationship between reported PEB and socio-demographic factors. The results showed that only households with separate units yielded a statistically significant but weak positive relationship with PEB (Table 3.3). Though not significant, there were expected positive relationships between PEB and gender, age, and education and negative relationships between PEB and number of children below 5 years, household size, free electricity, and access to social grants.

Table 3.3 Spearman's rank correlation analysis for PEB and socio-demographic factors.

Variable	Valid N	Spearman R (rho)	t-(N-2)	p-Value
Gender Dummy (Female = 1; Male = 0)	214	0.008	0.111	0.911
Age	216	0.092	1.345	0.180
Number of children below 5 years	218	-0.067	-0.989	0.324
Education	176	0.140	1.868	0.063
Household size	218	-0.064	-0.947	0.344
Access to social grant	218	-0.059	-0.861	0.390
Access to free electricity	217	-0.011	-0.168	0.867
Number of rooms	218	0.070	1.037	0.301
Separate housing units	218	0.164	2.443	0.015 *
Separate electricity meter	140	-0.118	-1.391	0.167

(* = $p < 0.05$) denotes significant difference.

It is expected that households with separate units can report sustainable electricity-use behaviour, possibly because they may feel that they have control and are accountable for the amount of electricity they use at any given time as compared to households with shared units. It was also expected that recipients of Free Basic Electricity were going to report poor electricity-use behaviour because they do not pay for it (Musango, 2014), and hence they are bound to be wasteful as they are less accountable for the amount of electricity they use. The above observations concur with a study by Thondhlana and Kua (2016), which notes unsustainable electricity-use practices among recipients of free electricity.

3.3.5 Relationship between PEB and values

The results based on Spearman's correlation coefficient between PEB and values showed that five of the higher-order values (universalism, benevolence, self-direction, hedonism, and power) yielded positive and significant relationships with PEB (Table 3.4). However, the relationships between these value factors are generally very weak, with rho values ranging between 0.14 and 0.27. Though not significant, higher-order value factors such as stimulation, achievement, security, and spirituality showed a positive relationship with PEB but the latter was inconsistent with the expected relationship.

Table 3.4 Spearman's correlation coefficient between PEB and high-order value factors.

High-Order Value	Valid N	Spearman R (rho)	t-(N-2)	p-Values
Universalism	217	0.192	2.864	0.005 *
Benevolence	217	0.167	2.487	0.014 **
Stimulation	217	0.056	0.822	0.412
Self-direction	217	0.162	2.403	0.017 **
Hedonism	217	0.146	2.156	0.032 *
Achievement	217	0.119	1.761	0.080
Power	217	0.271	4.134	0.000 ***
Security	217	0.067	0.982	0.326
Spirituality	216	0.008	0.119	0.906

(* = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$) representing significant difference.

From the list of aggregated high-order values, self-transcendence values (universalism and benevolence) showed a positive and significant relationship with pro-environmental behaviour, which suggests that people who have a disposition towards environmental quality, nature, and aesthetic beauty and who care for others were more likely to be pro-environmental. Positive linkages between the love for nature, environmental quality, social relations, empathetic attributes (a cluster of values that form universalism) and pro-environmental behaviour have been reported elsewhere (Gärling, 1999; Hansla et al., 2008), including among high income households in South Africa (Williams et al., 2020). For instance, in a study examining individual involvement in solving social dilemmas, it was discovered in Gärling (1999) that most British individuals with an orientation to self-transcendence values corresponded positively to pro-social behaviour. In a study exploring relationships between value orientation and environmental concern, it was found in

Hansla et al. (2008) that most Swedish residents with dispositions to environmental concern and good social relations exhibited environment friendly behaviour. According to the Schwartz's Theory of Basic Values, biospheric values (universalism) are characterised by concern for larger society and usually result in environmentally friendly behaviour (Schwartz, 1994).

Counter-intuitively, self-direction, hedonism, and power values showed significant positive relationships with pro-environmental behaviour. A positive association between power and pro-environmental behaviour is consistent with findings by Williams et al. (2020) among high income households in South Africa. Usually these value factors are associated with elements of self-centeredness, and according to the literature, people holding this set of values are less likely to behave pro-environmentally (Lindén et al., 2006). Similarly, people who have an orientation to power often exhibit poor environmental behaviour as they might have the money to do things that are pleasing to them (Lindén et al., 2006; De Groot and Steg, 2007; Hasanuzzaman et al., 2008). However, the meaning of values could be different in different settings. For instance, the interpretation of power from our study might not relate to material possession or personal comfort but to the ability of individuals to change situations (Laverty, 2011). These sentiments are supported by the author of Schwartz (1994) who argue that most of these values are context-specific. Moreover, it should be noted that most people rarely reflect about what is important to them since these value orientations are based on reported behaviour (Hansla, 2008). Hence, people might not have clear answers about their actual value orientations.

3.3.6 Predictors of PEB

The generalised linear regression analysis results show that only two factors, inclination to power and education, predicted PEB (Table 3.5). Negative correlation coefficients were recorded for socio-demographic factors such as number of rooms, household size, separate meters, and employment status, and on high-order value factors such as universalism, benevolence, stimulation, self-direction, achievement, and security.

Table 3.5 Determinants of electricity-use behaviour.

Variables	Coef. Estimate	Std. Error	Wald Stat.	P
Intercept	1.021	0.129	62.451	0.000 *
Gender (1 = female; 0 = male)	0.006	0.045	0.016	0.900
No. of rooms	-0.002	0.005	0.201	0.654
Age of household members	0.001	0.001	3.332	0.068
Household size	-0.010	0.006	2.475	0.116
Number of people below 5	0.024	0.018	1.677	0.195
Number of people above 65	0.018	0.019	0.875	0.350
Educational status	0.035	0.015	5.826	0.016 **
Employment status (1= employed; not employed)	-0.050	0.031	2.495	0.114
Grants (1 recipient; 0 non-recipient)	0.014	0.016	0.767	0.381
Free electricity (1 = recipient; 0 = non-recipient)	0.019	0.012	2.616	0.106
Separate meter	-0.028	0.022	1.747	0.186
Universalism	-0.001	0.023	0.002	0.968
Benevolence	-0.012	0.022	0.307	0.579
Stimulation	-0.004	0.013	0.076	0.783
Self-direction	-0.009	0.027	0.113	0.737
Hedonism	0.032	0.023	1.938	0.164
Power	0.057	0.021	6.948	0.008 **
Achievement	-0.020	0.023	0.748	0.387
Security	-0.021	0.024	0.749	0.387
Spirituality	0.011	0.012	0.935	0.334

(* = $p < 0.05$ and ** = $P < 0.01$) representing significant relationship.

The regression model provides some insights that are important for the understanding of electricity use-behaviour. For instance, the results are consistent with previous studies which showed that education had a significantly positive relationship with electricity-saving behaviour (Abrahamse and Steg, 2009; Schwartz, 1994). Most studies suggest that people who are educated are generally more aware about the environmental impacts of their behaviour and hence are likely to engage into environmentally friendly behaviour (Abrahamse and Steg, 2009). According to Schwartz (1994), having education represents a certain level of understanding, which translates into an

understanding of complex issues that guide our behaviour. This implies that more focus needs to be directed towards raising education and awareness among groups that have low levels of education. For instance, a study by Kua and Wong (2016) in Singapore found that educating households about electricity-saving strategies had the capacity to reduce electricity consumption by two percent. If similar initiatives are employed in the South African context, this might contribute huge electricity savings, given that low-income households constitute most of the South African population.

The results also showed counter-intuitive results concerning the influence of power on environmental behaviour. However, in a developing country context, the issue of power might be understood differently. For example, in poor communities, powerful people (e.g., politicians, religious and community leaders) are those who have a high social status and often want to lead by example and contribute to the welfare of the society (Chatterjee et al., 2019). Hence, this might explain the positive effect of power on PEB.

Consistent with previous studies (Abrahamse and Steg, 2009; Poortinga, 2004), household size had a negative relationship with electricity-saving behaviour. This is perhaps explained by the fact that the bigger the household, the more difficult it can be to assign electricity-saving duties, and hence such households are bound to be wasteful (Abrahamse and Steg, 2009). Surprisingly, about 70% of the value domains had a weak negative relationship with electricity-saving behaviour, which supports the argument by Lindén et al. (2006) that there is no universal application of value factors on behaviour.

3.4 Policy implications

Wasteful household electricity-use behaviour results in unnecessary losses with negative implications for electricity demand. Sustainable electricity-use practices might lead to grid stability, and minimising the pressure on the grid enables service providers to provide sufficient electricity for everyone. Moreover, reducing electricity wastages at the household level can minimise financial resources directed towards electricity purchases, thereby alleviating energy poverty among low-income households. Although the environmental benefits of sustainable electricity use may appear insignificant at the household level, saving electricity is important given the collective impacts of wasteful electricity-use practices on the country's carbon emission factor.

Hence, leveraging responsiveness by policy makers, practitioners, and service providers in promoting behavioural change can yield socio-economic and environmental benefits.

The positive behaviour reported in this study can be used as a basis for developing electricity-saving strategies encompassing other wasteful practices. Concerning wasteful behaviour, there is a need for policy interventions to address standby power losses on household appliances. TVs, satellite boxes, and stereos use electricity when they are on standby mode, which translates into unnecessary electricity wastages (Sahin and Koskal, 2014). The losses could be quite substantial considering that most households own such entertainment gadgets in South Africa. In response, stringent measures aimed at promoting the manufacturing and purchasing of energy-efficient gadgets (e.g., smart TVs) might provide a pathway to reducing standby losses, as seen in the EU (Gerber et al., 2019). However, technical interventions alone might be insufficient to address wasteful electricity-use practices, particularly in contexts where households might not be able to afford to replace or purchase ‘wasteful appliances’. Therefore, technical interventions should be combined with behaviour change interventions such as awareness raising campaigns, highlighting the socio-economic and environmental benefits of good electricity-use behaviour.

For instance, raising awareness about the load profile of household appliances might result in behaviour change and reduction in standby electricity losses. A load profile estimation conducted by Chatterjee et al. (2019) found out that the average hourly consumption for a basic television is 60 watts, and considering that a TV is used for about 3 h per day, this translates to about 180 watts per day. Following Eskom standards (Musango, 2014), a basic television consumes 20% of the actual consumption when it is on standby mode. Thus, in principle, a television set completely switched off for 21 h can save up to 252 watts per day or approximately 7.6 kWh per month. In our context, the average electricity consumption per household is approximately 162 kWh per month; thus, switching off TVs completely when not in use can save roughly 5% of electricity monthly. Another illustration relates to the use of refrigerators. According to Hasanuzzaman et al. (2020), the average wattage for a refrigerator is about 130 watts. This means switching off an empty refrigerator can result in electricity use of up to 3 kWh per day, or 2 kWh if the refrigerator is used for the recommended 8 h per day. In the context of this study, these potential electricity savings can translate into reduced electricity bills for households already struggling to meet daily

electricity needs, and money saved can be used for other basic needs. Further, electricity savings can translate into reduced electricity demand and carbon emissions.

In designing electricity-saving interventions, efforts that build on the values people consider important might yield electricity savings. In other words, if electricity-saving strategies can clearly show linkages with elements of universalism, such as nature loving, environmental quality, and empathy, they can trigger responsiveness by the users of electricity. Findings on the determinants of behaviour suggest policy makers and service providers need to be cognizant of both the value orientations and socio-demographic determinants of behaviour in formulating rational and meaningful interventions. This implies that interventions should be context-specific and should not be implemented independent of the end-users as the initial beneficiaries of the initiatives. Beyond benefiting the end-users, reductions in electricity can also be beneficial for local municipalities and service providers as they are mandated with providing basic services. In South Africa, municipalities that use electricity beyond their allocated monthly quota are penalized financially or risk being disconnected from the grid by the power utility, Eskom (Eskom, 2020). Thus, implementing behavioural interventions can result in reduced electricity demand by households. On the other hand, considering Eskom's bad financial situation (Eskom, 2020), reductions in electricity use would mean a reduced need for increasing electricity generation and related maintenance costs. This implies that electricity reductions at household level are beneficial to several stakeholders. Hence, there is a need for collaborative initiatives aimed at formulating the problem (electricity wastages) and interventions for addressing the problem, as has been suggested elsewhere (Ambole et al., 2020). For example, the provision of electricity-saving tips to households in the form of stickers and pamphlets has been shown to yield substantial electricity savings, though there is evidence of households reverting to wasteful electricity-use practices post interventions (He and Kua, 2013; Nahiduzzaman et al., 2018).

3.5 Conclusions

This study has come up with several key issues that are salient to our understanding of electricity-use behavioural patterns, including factors that should be considered in creating relevant and rational interventions for behaviour change. The findings show that among low-income households, there is evidence of both electricity saving and wasteful practices. Key areas of

concern relate to the potential prevalence of standby electricity losses and the use of kitchen appliances such as the refrigerator. When these findings are considered relative to other studies, it appears that wasteful electricity practices are prevalent among both low-income and high-income households. Thus, there is potential for investment in behavioural interventions for promoting electricity-use behaviour. Such interventions should be informed by and reflect the values that people consider important and align with local people's interests, priorities, and needs to yield positive behaviour changes. From a policy perspective, local municipalities should invest in education and awareness programmes aimed at sensitising local households about the importance of electricity conservation, including reducing household electricity expenditure and minimising pressure on the national grid and disruptions to electricity supply. Drawing on lessons from similar programmes elsewhere may provide useful frameworks for initialising user-driven electricity-saving programmes.

Chapter 4: Co-designed interventions yield significant electricity savings among low-income households in Makhanda, South Africa.

Abstract

Human practices are at the centre of unsustainable electricity use at the household level, which means behaviour change strategies can form pathways towards electricity conservation. Although behaviour change interventions are useful in promoting electricity savings at the household level, they are rarely inclusive and informed by the users of electricity. Using a field-based experiment, this study examines the impact of co-designed interventions on household electricity consumption among low-income households in Makhanda, South Africa. The results show that co-designed interventions yielded significantly more electricity savings (5%) than prescriptive interventions (2%) over the intervention period. Participants households exposed to the co-designed interventions showed electricity savings of up to 14% post the intervention period, suggestive of positive persistent effects. Household size and employment status had a significant negative effect on electricity consumption while age, employment status and baseline electricity consumption yielded positive effects. Electricity savings were positively correlated with involvement and trust, perceived behavioural control, and the intention to act pro-environmentally. The results highlight that co-designed interventions can yield significant electricity savings, which can in turn, result in grid stability, and reduced electricity expenditures and carbon emissions. A key contribution of this study lies in advancing our understanding of the effects of user-driven approaches in yielding persistent electricity saving behaviour, which to date has not been a focus of intervention studies. In particular, the findings lend support to notions on supporting the agency of electricity users in co-developing solutions for local sustainability challenges.

Keywords: Electricity use; urban sustainability; co-designed interventions; behaviour

4.1 Introduction

Behavioural interventions for reducing electricity consumption have long been considered a promising pathway to achieving sustainable cities, and a growing body of literature interrogates the effectiveness of electricity-saving interventions (Nahiduzzaman et al., 2018; Tiefenbeck et al., 2019). Behavioural interventions have been applied across different dimensions ranging from residential to commercial buildings. For instance, a study by Newsham and Tiller (1994) on

Canadian commercial buildings examined the utility of stickers in prompting users to switch off their computers when they were not in use and found a 14% electricity consumption reduction over a period of two months. Kua and Wong (2012) showed that the use of stickers with electricity-saving information on household appliances, such as refrigerators, resulted in electricity reductions of up to 2% in Singapore. The eco-living programme in Singapore also highlights the effectiveness of combining stickers and leaflets, with a 15.8% reduction in electricity consumption among households (He and Kua, 2013). Mi et al. (2020) found that coupling environmental education information and cost-benefit feedback had the capacity to save electricity by about 21% among Chinese households. However, some studies have shown that behavioural interventions do not always yield persistent positive outcomes since electricity users tend to revert to wasteful habits post project intervention periods (He and Kua, 2013; Nahiduzzaman et al., 2018).

Despite the potential positive effects of these intervention strategies in engendering sustainable electricity-use practices, their design is not informed by and does not allow the engagement of households in problem formulation (i.e., formulating the sustainability challenge), and interventions for addressing it (Mardookhy et al., 2014; Alrashed and Asif, 2015). The outcome is that behavioural interventions tend to be rather prescriptive and not user driven.

In the context of developing countries, investment in programmes for supporting the engagement of households in environmentally friendly, sustainable electricity behaviour is important for several reasons. First, such investment helps to alleviate energy poverty, hence increasing energy security (Gonzalez-Eguino, 2015; Mbewe, 2018). Second, it influences agency, that is, the ability to act in one's interest (Archer, 1995). Third, it helps in establishing a balance between electricity supply and demand, so limiting the pressure on the electricity grid. For instance, the South African energy sector is in a financial crisis and cannot afford to construct new or maintain existing electricity infrastructure (Eskom, 2020); therefore, investing in behavioural interventions can contribute to efforts aimed at promoting electricity conservation in South Africa (Allcott and Rogers, 2014; Ornaghi, 2018).

Consideration of local people's views is important for developing a common understanding of the sustainability challenge and co-designing electricity-saving interventions (Ambole et al., 2019;

Thondhlana et al., 2021). Many interventions for encouraging electricity savings are arguably externally driven and unsustainable as they are seldom co-designed with input from key stakeholders, such as electricity suppliers, providers, and users (Klein and Coffey, 2016; Batinge et al., 2016; Ambole et al., 2019). This means that, while interventions are designed with good intentions, they may be socially void and irrelevant. Further, research that focuses on the persistent effect of interventions is limited (He and Kua, 2013; Mtutu and Thondhlana, 2016; Nahiduzzaman et al., 2018). User-driven behavioural interventions are characterised by collective problem formulation, co-designed solutions, and the involvement of households as key partners (Ssozi-Mugarura et al., 2017). Processes that engender co-generation and sharing of knowledge and the creation of trust between actors are likely to yield persistent effects (Ambole et al., 2019; Popa, 2015). Further, in co-designed processes, the impacts transcend the effects of interventions on electricity saving and might include effects that cannot be easily measured, such as increased agency, decision-making capacity, involvement in and ownership of the project (Lang et al., 2012). Thus, the integration of behaviour theories and transdisciplinary approaches can be useful for understanding the transition to sustainable use. The consideration of knowledge co-production and co-designing interventions in promoting pro-environmental behaviour is consistent with recent efforts to highlight the importance of collaborative processes for designing locally relevant solutions to environmental problems (Yang and Sung, 2016; Ssozi-Mugarura et al., 2017; Daudin et al., 2021; Thondhlana et al., 2021;).

4.1.1 Theoretical framing

Transdisciplinary approaches are important in designing behavioural interventions for sustainable electricity use because they encourage collaboration between different actors with an interest in electricity use who collectively formulate problems or sustainability challenges (Daudin et al., 2021; Thondhlana et al., 2021). Transdisciplinary approaches can support established theories for studying human behaviour. One of the commonly used theories is the Theory of Planned Behaviour (TPB) (Figure 4.1). The TPB suggests that people's behaviour in any given context is determined by intentions that emanate from personal attitudes, subjective norms, and perceived behavioural control (Ajzen, 1991). Attitudes measure the favourability of certain behaviours for individuals (Ajzen, 1991). For example, Gadenne et al. (2011) have found a positive correlation between people who have a positive attitude towards switching off appliances when leaving the

room and actual electricity-saving behaviour. It can be argued that adopting a transdisciplinary approach that facilitates collective problem formulation and co-designing electricity-saving interventions can promote positive attitudes towards interventions which can result in electricity conservation (Beckman et al., 2007; Nevens et al., 2013). It is plausible to assume that the involvement of electricity users in problem formulation can ensure alignment of research project goals with electricity users' needs, and activate electricity users' agency, which subsequently changes their attitudes towards electricity saving. In transdisciplinary processes, new and creative ways for diverse stakeholders to work together across paradigms emerge for the purposes of knowledge transfer, translation, and ultimately, transformation centred on novel to complex problems (Carlie, 2004; Max-Neef, 2005). For instance, Heaslip and Fahy (2018) found transdisciplinary approaches had a positive effect on attitude change towards community energy transitions in Ireland. However, Albarracin et al. (2005) have questioned the extent of influence that attitudes have on behaviour, arguing that attitudes are not a function of personal attributes only, and cannot adequately translate into pro-environmental behaviour, especially when there are external constraints to undertaking the desired behaviour. This means that the context within which attitudes are developed or changed is important in understanding behavioural responses.

Perceived behavioural control is the extent to which one believes one has the means, opportunity, and ability to control the outcome (Ajzen, 1991). It is determined by how easy or difficult performing a behaviour is perceived to be (Gilg and Barr, 2005). If a person perceives the task as easy to perform, then that person is more likely to do it. Ajzen (1991) has identified economic requirements, time duration, and convenience as the main factors affecting perceived behavioural control. Perceived behavioural control has also been found to be a critical factor in determining actual reductions in electricity use as Ru et al. (2018) discovered among Chinese households.

The Theory of Planned Behaviour also underscores the influence of subjective norms on behaviour. Subjective norms refer to the supposed expectations of significant figures surrounding the subject or the pressure from the society to behave in a certain way (Ajzen, 1991). Ajzen (1991) suggests that the perception of significant figures (e.g., respected members of the society and family members) has a very strong influence on behaviour. Dixon et al. (2015) found a positive correlation between subjective norms and intention to save electricity in the workplace. However,

the influence of subjective norms on behaviour has been criticised as more applicable to visible behaviours (e.g., waste dumping) than non-visible ones (Manning, 2009) such as electricity use. Generally, there is a growing recognition that complex challenges, such as energy insecurity, require the participation of stakeholders, typically including scientists, experts, and civil society (Popa et al., 2015) in generating context-specific knowledge (Polk, 2014).

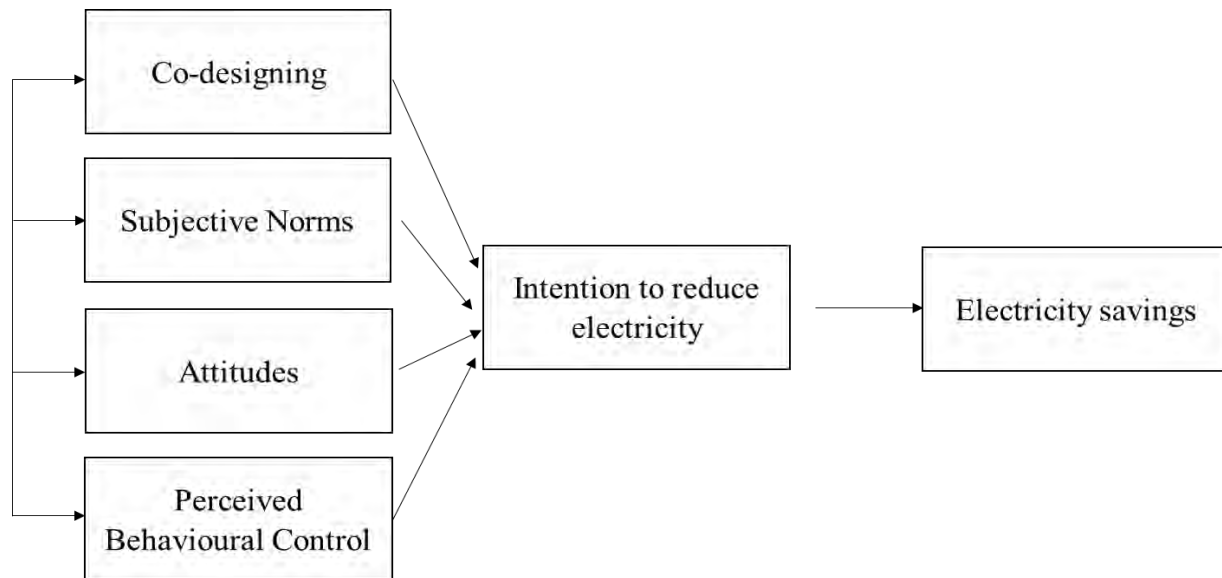


Figure 4.1 Determinants of electricity-use behaviour

4.1.2 Behavioural interventions and electricity use in South Africa

In South Africa, several behavioural interventions for minimising electricity consumption have been implemented in different settings with varying degrees of success. For instance, the 49 Million Campaign, an initiative launched by the country's main electricity distributor, Eskom, was meant to provide awareness to all South Africans to use electricity sustainably (Department of Energy South Africa, 2012). Thondhlana and Kua (2016) examined the utility of behavioural interventions from a low-income household setting and found an average reduction of 24.5 kWh in a period of four months among households who received a full package of interventions, including electricity-saving tips (on stickers and pamphlets), discussions and reminders. Bulunga and Thondhlana (2018) have also showed that behavioural interventions yielded electricity savings in a university setting, with residences that received the full set of treatment showing the lowest rate of increase in consumption (3%) compared to those who received partial treatments (11%) or

no treatment (12.5%). However, these studies were mainly researcher-driven, undertaken over short periods, and did not measure the persistent effects of the interventions. Although such types of studies are very important, they are extractive and do not consider the views of the users of electricity.

Consistent with the literature, the study hypothesises that the involvement of user households in problem formulation and designing interventions can improve their knowledge of the purpose of the project, and their sense of control over their electricity-use behaviour. The above-mentioned hypothesis is based on the suggestion that including civil society in the formulation, discussion, and crafting of interventions enables them to reflect on their ideas, which boosts their control over issues affecting them (Mauser et al. (2013). Moreover, based on the literature (e.g., Poteete et al., 2010; Cox et al., 2014), this study also hypothesises that perceptions of the importance of household members and other respected members of the society will result in electricity savings.

This study aims to make a comprehensive contribution to the existing literature on sustainable electricity consumption by providing a behavioural perspective from a low-income household setting which is arguably marginalised and under-represented in the literature. Such an analysis is important in identifying context-specific and sustainable household electricity-use interventions. Moreover, interventions that are informed by an understanding of actual electricity consumption are bound to be realistic and long-lasting, and hence they are more likely to be accepted (Popa et al., 2015). The purpose of this study was to examine the effects of co-designing behavioural interventions on electricity use among low-income households in Makhanda, South Africa. To the best of our knowledge, this is the first study in South Africa that examines electricity consumption among households over a relatively long period of time (about two years), and that integrates transdisciplinary approaches with behavioural theories in designing the interventions. A key contribution of this study lies in advancing our understanding of the effects of user-driven approaches in yielding persistent electricity saving behaviour, which is arguably underrepresented in the literature. From a practical perspective, this paper highlights the value of collective problem formulation as a basis for co-designing socially relevant and meaningful electricity-saving

interventions. This approach can enable the alignment of local needs, interests, and priorities with research enquiry.

4.2 Methods

4.2.1 Study participants

The study was undertaken among low-income households in Makhanda, a medium-sized town located in the Eastern Cape Province of South Africa (33°18'36"S; 26°31'36"E). The study is part of the Leading Integrated Research for Agenda 2030 in Africa (LIRA2030), a five-year programme aimed at supporting the production of “high-quality, inter- and transdisciplinary, solution-oriented research on global sustainability by early-career scientists in Africa” (<https://council.science/what-we-do/funding-programmes/lira2030/>). The population of Makhanda is about 70 000 people (Statistics South Africa, 2017). The Eastern Cape province is one of the poorest provinces in South Africa, characterised by high levels of illiteracy and unemployment (33%) (Statistics, South Africa, 2011). Owing to high levels of poverty and unemployment, over 40% of the province’s population are recipients of government social grants (Statistics, South Africa, 2011), a common characteristic in many South African towns. Consistent with many South African towns, Makhanda is characterised by some apartheid spatial arrangements (Freund, 2007): the town is divided into two main areas, the western side and the eastern side. The western side is characterised by high-income households, good educational facilities including state and private schools, a university, and good basic social amenities. The eastern side is characterised by low- to medium-income households and consists of three types of housing: privately built blockhouses, state-built houses, and informal houses (locally known as shacks). Like most towns in South Africa, though many low-income households are connected to the national grid, they are energy poor and insecure (Eskom, 2019), and receive Free Basic Electricity units of 50 kWh per month. In this study, participating households were selected from the four low-income neighbourhoods of Hlalani, Fingo, Joza, and Tanti. The neighbourhoods were purposively selected because they had households that volunteered to participate in the study over two years.

4.2.2 Study design

The study was conducted between August 2019 and June 2021. For accurate estimation of the experimental effect of treatment factors (interventions), the study dealt with non-experimental factors, such as weather, that are difficult to control by using simultaneous events, that is, using multiple treatment groups experiencing the same conditions at the same time (Mi et al., 2020). By conducting the study over two years, all four seasons of the year were considered. The coldest months in Makhanda are in the austral winter between May and August, which represents the peak period for electricity usage for heating, cooking and entertainment as people spend more time indoors, and the effects of the intervention strategies on electricity saving can be better compared during this period.

Participant households were selected from Tentyi, Joza, Pumlani, Vukani, and Fingo suburbs using a convenience sampling approach via social hubs such as churches and local societies with the assistance of local volunteers (champions). Within each participant household, household heads and, in their absence, the eldest adult member of the family with a fair understanding of electricity use practices in the household were targeted for the study. The community champions were individuals who were selected to facilitate community engagements based on their positions in the communities (e.g., ward councillor, youth leaders, and church leaders). Prior to commencement of the project, all community champions received advanced scientific training on data collection tools, interpretation of electricity-saving interventions, and collection of electricity consumption data. The champions were also instrumental in designing data collection instruments by acting as conduits between the researchers and participant households, particularly in making data collection instruments reflective of and meaningful to the participant households' context. The experiment had three stages.

Stage 1: Baseline data

Following problem formulation and design of data collection instruments, electricity consumption data were collected between October 2019 and January 2020. The socio-demographic information of the participant households, electricity-use behaviour and electricity consumption data were collected using a household questionnaire. Across all four study sites, a total of 297 households

selected from Tentyi, Joza, Pumlani, Vukani, and Fingo suburbs participated in the first stage of the project.

Stage 2: Intervention period

The experiment used varied application of interventions, where participants were allocated into the Full Treatment (FT), Partial Treatment (PT) and Control (C) through volitional choice. All households were informed by the community champions about the length of the electricity-saving programme, the various activities of the project, and participants' roles in each of the treatment groups and, based on this information, households were invited to join the respective groups. The community champions also used their experience of working with participant households during the problem formulation stage to measure the level of engagement and interest, which was used to allocate undecided households to treatment groups. In the second stage, 56.6% of households pulled out for various reasons including loss of interest, research fatigue, and work commitments; hence, their electricity consumption data were incomplete. Subsequently, only 132 households (44.4%) with complete data were considered in the analysis. Electricity-saving interventions were applied for 11 months between February 2019 and December 2019. Households in the FT group received a full set of interventions, including monthly meeting discussions on the importance of electricity saving to the household, ways of saving electricity given the respective household setting, pamphlets and stickers with co-developed electricity-saving tips, monthly discussions on the implementation and usefulness of interventions and challenges faced in implementing the interventions, and self-monitoring of monthly electricity consumption. The electricity-saving tips such as switching off lights and home appliances completely when not in use, unplugging chargers from sockets, not overloading refrigerators, placing refrigerators from heat sources and boiling just enough water for coffee or tea were drafted following Eskom Demand Side Management (Demand Side Management, 2008) but adjusted to suit the study's context. Households in the FT group received a full set of interventions, including pamphlets and stickers with co-developed electricity-saving tips, monthly discussions on the benefits of electricity saving, challenges faced in implementing the interventions and performance feedback. A workshop with all the FT households was conducted in the month of October 2019 for a reflective exercise on the usefulness of electricity-saving interventions, challenges encountered, and potential solutions. Throughout the intervention period, the champions played a key role in the learning process, including monthly

visits to participant households and in facilitating small group meetings and reflective workshops. During monthly visits to participant households in the FT group, discussions facilitated by the champions centred on participant households' electricity consumption relative to previous months' consumption as a basis for encouraging electricity-saving behaviour. This approach also enabled identification and understanding of barriers to electricity saving and in designing appropriate responses.

Households in the PT group received pamphlets and stickers with electricity-saving information exclusively designed by the researchers. No further interventions such as monthly meetings with champions and performance feedback were applied, but participant households were asked to record their monthly electricity consumption. Households in the Control group did not receive any interventions but knew about the project. In the seventh month (September 2020) of the intervention period, households in the FT and PT groups were asked to evaluate the usefulness of the programme and electricity-saving guidelines based on their experiences.

Stage 3: Post-intervention electricity consumption

Active application of electricity-saving interventions through discussions and feedback ended in December 2020. To test the persistent effect of interventions, electricity consumption was recorded for six months between January 2021 and June 2021 across the three treatment groups. The respondents were selected to participate based on their willingness to participate further in the study. A total of 67 households participated in the post-intervention experiment. A total of 67 households participated in the post-intervention experiment, consisting of 21, 22 and 24 households in the FT, PT and Control group respectively. During the post-intervention period, the community champions collected electricity consumption data only.

4.2.3 Measures

Socio-demographic factors

A questionnaire was used to collect the socio-demographic profile of all the participant households including gender, age, level of education, and employment status of the respondents, household size, number of rooms and social grant status, whether the household was a recipient of the

government Free Basic Electricity. The respondents were asked to indicate all the electric appliances they owned.

Electricity consumption data

All the participant households had prepaid electricity meters. The amount of monthly electricity consumption was calculated from the reported electricity expenditure divided by the average unit cost (R0.58) per kWh. For households that received Free Basic Electricity, 50 kWh was added to the recorded monthly consumption.

Perceived Behavioural Control (PBC)

To measure PBC the participants in the FT and PT groups were asked questions such as: “How much control do you have over reducing electricity consumption in your household?” (1 = no control, 2 = little control, 3 = neutral, 4 = some control, 5 = great control); How difficult is it for you to reduce electricity consumption in the household?” (1 = very difficult; 2 = difficult; 3 = neutral; 4 = easy; 5 = very easy); and “It is my choice whether I reduce household electricity consumption” (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). “The amount of electricity saved is determined by family members”; “I have full control over the amount of electricity that I use”; again, these were rated on a 5-point Likert scale (1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree).

Subjective norms

To measure subjective norms, participants were asked about their perception of the approval of the significant others on electricity saving. For example, participants were asked to respond to the question, “If I save electricity, the people significant to me would...” (1= completely disapprove, 2 = partially disapprove, 3 = neutral, 4 = approve, 5= completely approve). In the second stage, the participants were asked to evaluate their perception of the significant others on electricity saving. For example, “Most people who are significant to me think that electricity saving is ...” (1 = very undesirable, 2 = undesirable, 3 = neutral, 4 = desirable, 5 = very desirable).

Motivation

The questionnaire measured motivation to ascertain consumer involvement with the electricity-saving interventions. The questionnaire asked questions such as, “Do you think reducing household electricity consumption is good for the environment?” (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). To measure the effect of feedback on behaviour we asked the question, “Knowledge about your previous month’s electricity savings encouraged you to implement interventions” (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

Ability

To capture the extent of knowledge possessed by the householders (how much householders feel they know about electricity saving) the questionnaire included questions such as “Electricity saving measures are easy to do”, with responses on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

Intentions

The questionnaire included questions aimed at measuring the participants' intention to save electricity including, “My intention to save electricity in my home is...” (1 = very weak, 2 = weak, 3 = neutral, 4 = strong, 5 = very strong), and “How likely are you to save electricity in your home in the next months?” (1 = very unlikely, 2 = unlikely, 3 = neutral, 4 = likely, 5 = very likely).

Perceived importance of the intervention programme

Questions aimed at assessing perceptions on the effects of the interventions and the co-design processes (collective problem formulation, co-designing and involvement) between the FT and PT included, “We have provided you with useful information about electricity reduction”, with responses on a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree). To check if co-design processes resulted in the development of a common interest and shared vision among FT participants and other stakeholders, the participants were asked if they felt there was general agreement on the sustainability challenge (electricity wastage), and the benefits of resolving the problem collectively. To gauge if collaborative processes resulted in trust-building, the participants were asked to indicate if decision making was perceived as open and fair, and information was shared and understood by all participants. The participants were also

asked to indicate if they were informed about what was happening (processes, activities, and expectations) in the project, and they thought their views and opinions were listened to) on a scale of 1–5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). The participants were also asked to provide explanations for their answers to provide contextual contours for understanding their experience of the project.

4.2.4 Data analysis

Mean monthly electricity consumption per household over the intervention period (baseline, intervention, and post-intervention) was calculated. Non-parametric tests were used for statistical analyses because electricity consumption data failed normality and homogeneity of variance after Levene's tests, that is, non-parametric tests were used for statistical analyses. Comparison of electricity between and within groups, before, during, and post-intervention were conducted using the Difference-in-Difference (DID) approach, following Mi et al. (2020). The basic standard of the DID estimator is to measure the actual outcome of an intervention by comparing the differences between the treatment groups and the control, before and after treatment (Mi et al., 2020). The DID standard estimator eliminates interfering factors on the results, including primary (permanent) factors (e.g., socio-demographic factors and residential area) and secondary (dynamic) factors (e.g., changes in electricity prices and weather). The differences in reduction in electricity between months for each of the three groups were determined through Wilcoxon matched pairs tests, and the results are presented in the form of tables. Kruskal-Wallis tests were conducted to see if there were significant differences between groups. Comparisons of monthly electricity consumption between the FT and PT groups and the Control were performed using the Mann-Whitney U tests. The influence of socio-demographic factors on electricity consumption was examined through a Generalised Linear Regression Model (GLM). A correlation analysis was performed to examine the relationship between electricity consumption and socio-demographic and psychological factors, including personal values and subjective norms. All statistical analyses were conducted using Statistica version 14.0.

4.3 Results

4.3.1 Baseline characteristics of participant households

The results showed more male representation (65%) than female (35%) across the total sample and in all the treatment groups, with the biggest proportion in the Full Treatment (FT), followed by the Control, and the Partial Treatment (PT) (Table 4.1). The mean age for the total sample was about 50 years, and the mean household size was 4.4 persons. The average number of rooms was roughly 4.4 across the sample. The educational level across the sample was generally low, with most of the respondents (60%) having attained secondary education only (Table 4.1).

Less than a quarter of the participants had tertiary education. About 86% of the participant households across the treatment groups were recipients of social grants. A substantial proportion of the household members were not formally employed, and more than 50% of those who were employed received an income of less than ZAR10 000 (US\$668) per annum across all the treatment groups. Moreover, a substantial proportion of households were recipients of the government's Free Basic Electricity (50 kWh/month), which is a token given to support poor households. Generally, the socio-demographic profile of the households shows these findings show that the society under study had a relatively low standard of living.

About 63% of the participant households had separate housing units, while less than half (46%) had separate meters. Overall, there were no significant differences in any socio-demographic characteristics between treatment groups except for one variable, namely the proportion of households receiving social grants (Table 1). There were significantly more households that received government social grants in both the FT and PT groups (92% respectively) than the Control (73%). Taken together, the results suggest that most household characteristics are comparable and similar between the treatment groups.

Table 4.1 Socio-demographic features of households.

Variable	Treatment group			Total	Kruskal-Wallis (H)/ χ^2 test
	FT	PT	Control		
Gender (%) of participants					
Female	28	41	38	35	$\chi^2 = 1.83$; p = 0.40
Male	72	59	62	65	
Mean age of participant	50.9 ± 16.0	48.5 ± 17.2	49.5 ± 16.7	49.8 ± 16.4	H = 0.665; p = 0.717
Mean household size	4.7 ± 2.2	4.4 ± 2.4	4 ± 1.9	4.4 ± 2.2	H = 2.583; p = 0.275
Mean number of rooms	4.6 ± 1.4	4.3 ± 1.4	4.2 ± 1.4	4.4 ± 1.4	H = 3.114; p = 0.211
Proportion (%) of households receiving social grants	92	92	73	86	$\chi^2 = 8.68^{**}$; p = 0.013
Education level (%)					$\chi^2 = 4.89$; p = 0.56
No education	5	3	11	6	
Primary	22	21	17	18	
Secondary	59	67	50	60	
Tertiary	14	9	22	16	
Mean number of people employed	0.5 ± 0.75	0.9 ± 1.18	0.8 ± 0.7	0.8 ± 0.87	H = 3.019; p = 0.221
Employment status of Participant (%)					$\chi^2 = 5.70$; p = 0.68
Full time	55	63	53	57	
Part time	36	34	36	35	
Unemployed	9	3	9	7	
Other			2	1	
Income group (%)					$\chi^2 = 5.47$; p = 0.71
0-10 000	54	63	50	55	
10 001-30 000	37	34	39	37	
30 000 and above	9	3	11	8	
Proportion (%) receiving Free Basic Electricity)	58	38	48	49	$\chi^2 = 3.53$; p = 0.17
Proportion (%) of homesteads with separate units	64	57	67	63	$\chi^2 = 1.03$; p = 0.60
Proportion (%) of houses with separate meters	51	48	39	46	$\chi^2 = 1.03$; p = 0.60

(* = p<0.05, ** = p<0.01) representing significant differences.

4.3.2 The effects of interventions on electricity consumption

The average baseline electricity (electricity usage before intervention) consumption per capita was significantly higher for the Control (41.83 kWh) than the FT (36.55 kWh) and PT (31.84 kWh) (Table 4.2). Significant differences in monthly electricity consumption before intervention were recorded in the months of October and November (2019) but not in December (2019) and January (2020) (Table 4.2). For the first three months (February, March, and April) following initialisation

of electricity-saving interventions, there was a decrease in electricity consumption (savings) in all groups for all months, except for the two months of February and April in the PT group (Table 4.2). An increase in electricity consumption relative to baseline was recorded in all groups (except for FT and PT in July) between May and July 2021 (austral winter months). The rate of increase in May was lower (0.47%) in the FT than in the PT and Control, which was 7.63% and 2.49% respectively, although statistical analysis showed no significant differences between groups.

In June 2020, the lowest increase in electricity consumption (5.93%) was in the FT group, followed by the PT (8.35%) and Control (8.63%) groups. Both the FT and the PT groups showed electricity savings in the coldest month of July while the Control showed an increase in electricity consumption. The FT showed the highest month-on-month increase in electricity savings ranging from 2% in July 2020 to 22% in December 2020 relative to the PT and Control groups (Table 4.2).

Between July and December 2020, the PT and Control groups showed significantly higher electricity consumption per capita in all months than the FT group. Marginal differences in electricity consumption between Control and PT were recorded from August through November. There was a significantly marked difference in electricity consumption and change in consumption relative to baseline between the FT and PT groups in December 2020. Furthermore, statistical analysis showed that the mean percentage reduction in electricity consumption between September and December for the FT was nearly five times that of the PT (2.69%) and seven times that of the Control group (1.81%). On average, the FT group reduced electricity consumption by 5.45%, followed by the Control and PT groups, which reduced electricity by 1.15% and 0.98%, respectively, from the baseline consumption during the intervention period.

Table 4.2 Mean ($\pm$ SD) monthly household electricity consumption (in kWh) changes before and after interventions. Electricity savings (reductions) and increases in consumption are represented by positive and negative values (%) in brackets respectively.

Month	Treatment group			Kruskal-Wallis (H) -Test
	FT	PT	Control	
October 2019	37.68 $\pm$ 13.32 ^a	31.31 $\pm$ 11.37 ^a	47.60 $\pm$ 26.42 ^b	$H = 15.359$ $p = 0.0001^{***}$
November 2019	36.94 $\pm$ 14.56 ^a	30.06 $\pm$ 10.75 ^a	41.26 $\pm$ 17.71 ^b	$H = 9.730$ $p = 0.008^{**}$
December 2019	37.28 $\pm$ 19.59	33.93 $\pm$ 12.90	40.70 $\pm$ 21.73	$H = 1.4342$ $p = 0.488$
January 2020	34.28 $\pm$ 15.99	32.06 $\pm$ 12.29	37.77 $\pm$ 18.70	$H = 2.560$ $p = 0.278$
Average Baseline	36.55	31.84	41.83	
February 2020	35.00 $\pm$ 14.88 (4.24%)	34.58 $\pm$ 12.94 (-8.61%)	37.65 $\pm$ 17.90 (9.99%)	$H = 0.883$ $p = 0.643$
March 2020	35.7 $\pm$ 16.24 ^a (2.33%)	29.61 $\pm$ 9.43 ^a (7%)	39.60 $\pm$ 16.47 ^b (5.33%)	$H = 7.493$ $p = 0.024^*$
April 2020	35.88 $\pm$ 15.68 (1.83)	33.27 $\pm$ 10.96 (-4.49%)	40.48 $\pm$ 16.20 (3.23%)	$H = 4.579$ $p = 0.101$
May 2020	37.26 $\pm$ 17.11 (- 0.47%)	34.27 $\pm$ 9.93 (-7.63%)	42.87 $\pm$ 15.69 (-2.49%)	$H = 4.203$ $p = 0.122$
June 2020	38.72 $\pm$ 20.21 (-5.93%)	34.50 $\pm$ 9.64 (-8.35%)	45.44 $\pm$ 17.81 (-8.63%)	$H = 6.531$ $p = 0.038^*$
July 2020	35.71 $\pm$ 17.65 ^a (2.30%)	31.44 $\pm$ 11.27 ^a (1.26%)	42.79 $\pm$ 19.14 ^b (-2.30%)	$H = 7.032428$ $p = 0.030^*$
August 2020	35.49 $\pm$ 17.66 (2.90%)	32.09 $\pm$ 12.66 (-0.79%)	40.59 $\pm$ 18.18 (0.57%)	$H = 4.808$ $p = 0.090$
September 2020	32.28 $\pm$ 14.17 ^a (11.68%)	29.66 $\pm$ 9.66 ^a (6.85%)	40.50 $\pm$ 19.07 ^b (2.96%)	$H = 9.116$ $p = 0.011^{**}$
October 2020	32.76 $\pm$ 13.84 ^a (10.37%)	31.54 $\pm$ 9.80 ^a (0.94%)	41.37 $\pm$ 17.11 ^b (1.10)	$H = 9.854$ $p = 0.007^{**}$
November 2020	33.46 $\pm$ 13.60 ^a (8.45%)	31.53 $\pm$ 10.30 ^a (0.97%)	42.02 $\pm$ 14.95 ^b (-0.45%)	$H = 11.1522$ $p = 0.004^{**}$
December 2020	28.41 $\pm$ 15.43 ^a (22.27%)	31.21 $\pm$ 9.35 ^b (1.98%)	40.42 $\pm$ 17.38 ^b (3.37%)	$H = 11.014$ $p = 0.004^{**}$
Mean electricity savings (%) August -December	11.13%	1.99%	1.51%	
Mean electricity savings (%) Overall savings	5.45	-0.98	1.15	

(* = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$) representing significant differences.

4.3.3 Post-intervention electricity consumption

To evaluate the persistent effects of electricity-saving interventions, the study measured monthly electricity consumption between January 2021 and June 2021 (after the interventions) for all the three treatment groups. Significant differences in mean monthly household electricity consumption were noted between the treatment groups for all the months (Table 4.3). The results showed a significant decrease from the baseline consumption in both the FT and PT groups, ranging from 9.7% to 19.2% for the former and 7% to 11% for the latter (Table 4.3). Over the post-intervention period, the FT group showed high mean electricity savings with the highest percentage reduction (19.2%) recorded in May as compared to 11% recorded in the PT group. On the other hand, an increase in electricity consumption relative to baseline was recorded for the Control group across all the post-intervention months, with the highest (11.2%) rate of increase in June 2021 and the lowest (9.8%) in March 2021 (Table 4.3). On average, the reduction in electricity consumption over the post-intervention period for the FT (13.8%) was higher than that of the PT (8.8%). In contrast, electricity consumption increased by 10.6% (relative to baseline) for the Control group.

Table 4.3 Post-intervention monthly mean electricity consumption relative to baseline. Electricity savings (reductions) and increases in consumption are represented by positive and negative values (%) in brackets respectively.

Month	Treatment group			Kruskal-Wallis (H)-Test
	FT	PT	Control	
Baseline consumption (kWh)	36.55	31.84	41.83	
January	31.32±13.02 ^a (14.3%)	29.17±8.07 ^a (8.4%)	45.93±15.72 ^b (-9.8%)	H= 10.028 p = 0.007**
February	33.02±13.93 ^a (9.7%)	29.31±8.45 ^a (7.9%)	46.32±15.15 ^b (-10.7%)	H = 10.749 p = 0.005**
March	31.87±13.98 ^a (12.8%)	29.44±8.85 ^a (7.5%)	46.52±15.76 ^b (-11.2%)	H = 10.257 p = 0.006**
April	32.00 ± 12.85 ^a (12.4%)	28.34±10.14 ^a (11%)	46.12±14.52 ^b (-10.3%)	H = 13.242 p = 0.001***
May	29.53 ± 12.88 ^a (19.2%)	28.98±8.26 ^a (9%)	46.26±14.97 ^b (-10.6%)	H = 11.851 p = 0.003**
June	31.23±13.30 ^a (14.3%)	28.92±7.95 ^a (9.2%)	46.52 ± 15.21 ^b (-11.2%)	H = 12.891 p = 0.002**

Mean (%) electricity savings between January and June	13.8	8.8	-10.63	
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(* = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$) representing significant differences.

4.3.4 Factors influencing electricity consumption

The results showed that household size and employment status had a significant negative relationship with electricity consumption. Baseline electricity consumption, age (6–17 years old), and employment status yielded a positive relationship (Table 4.4).

Table 4.4 Determinants of electricity consumption for FT households

Variable	Coef. Estimate	Std. Error	Wald. Stat.	p
Intercept	2.4770	0.1646	226.4229	0.000
Gender (1 = female; 0 = male)	-0.0280	0.0246	1.2895	0.256
Age of respondent	-0.0002	0.0015	0.0231	0.879
Household size	-0.0638	0.0190	11.2351	0.001***
Number of rooms	-0.0016	0.0151	0.0116	0.914
Employment status (1 = fulltime; 0 = Other)	-0.1343	0.0465	8.3295	0.004**
Number of people above 65 years	-0.0679	0.0445	2.3332	0.127
Number of people between 6 to 17 years	0.0678	0.0298	5.1654	0.023*
Baseline electricity consumption	0.0301	0.0019	229.6501	0.000***
Access to Basic Free Electricity (1 = Recipient; 2 = non-recipient)	-0.0290	0.0235	1.5136	0.219
Social grants (1 = Recipient; 2 = non-recipient)	-0.0012	0.0306	0.0017	0.967
Homestead has separate units	-0.0461	0.0285	2.6292	0.105

* = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$) representing significant relationship.

4.3.5 Relationship between electricity saving and socio-psychological variables

The results showed that all the considered factors, except one, yielded a positive relationship with electricity-saving, though only four factors yielded significant differences (Table 4.5). Feeling that views were represented, having control over the situation, ease of implementation of electricity-saving interventions, and the intention to save electricity in the future were all significantly positively related to electricity savings.

Table 4.5 Spearman correlation coefficient between electricity savings and socio-psychological variables.

Socio-psychological variables	Valid N	Spearman R (Rho)	T(N-2)	<i>p-value</i>
Concern				
Increased concern about the negative impacts of wasting electricity	37	0.138	0.822	0.042
Encouragement and satisfaction				
Encouragement	37	0.298	1.846	0.073
Sense of satisfaction	36	0.167	0.986	0.331
Feedback encourages	37	0.245	1.495	0.144
Involvement and trust				
You feel involved	37	0.097	0.577	0.568
Champions listen	36	0.119	0.700	0.489
My views are considered	37	0.341	2.143	0.039*
Information is from a trusted source	37	0.127	0.759	0.453
Communities have power to control their situation	37	0.151	0.901	0.373
Subjective norms				
If I save electricity, the people significant to me would approve	36	0.231	1.390	0.174
Electricity saving is the responsibility of everyone	36	0.0164	0.096	0.924
Perceived Behaviour Control				
Having control over the situation	35	0.355	2.181	0.036*
Ease of use of electricity-saving interventions	36	0.397	2.520	0.017*
It is my choice whether I reduce household electricity consumption	36	0.060	0.351	0.726
Intention				
Likely to save electricity in the future	37	0.349	2.203	0.034*

(* = $p < 0.05$) representing significant relationship.

Further analysis showed that 60% of respondents in the FT group shared electricity-saving information with household members compared to 36% for the PT group (Appendix 4A). About 82.5% of respondents in the FT group either agreed or strongly agreed that they changed their old wasteful electricity practices, compared to 57% for the PT. A slightly higher proportion (82%) of respondents in the FT than in the PT group (76%) said they were more concerned about saving electricity than before. More respondents (72%) in the FT than in the PT (47%) group reported a sense of satisfaction after implementing electricity-saving interventions. Marginal differences

were recorded between the FT and PT groups regarding the motivations for electricity conservation, including saving electricity to save money and saving electricity to stop electricity load shedding. About 60% of respondents in the FT group either agreed or strongly agreed that electricity-saving measures were easy to do, compared to 36% for the PT group. Lastly, approximately 80% of those in the FT group agreed that they felt involved in the electricity savings in their homes compared to 57% in the PT group.

4.4 Discussion

4.4.1 The effects of interventions on electricity consumption

The findings showed that the rate of savings was higher for the FT group than for the PT and Control groups. The differences in savings can be attributed to the differential treatment between the FT group (who received a full package of electricity-saving information including discussions, electricity-saving stickers and pamphlets) and the PT and Control groups who received prescribed interventions and no interventions, respectively. The rate of electricity savings by the FT group observed in this study (5%) was higher than the 2% found by Kua and Wong (2012). However, the overall reductions from this study were found to be lower than the 9% reported by Bulunga and Thondhlana (2018) in university residences, and the 14% found by Newsham and Tiller (1994) in Canadian commercial buildings. However, the electricity savings for the FT group post-reflection activities (September 2020 to December 2020) (11%) and post the intervention period (14%) showed that electricity conservation was comparatively high. This implies that discussions, sharing electricity-saving information, and collective problem formulation conducted with the FT group were effective in yielding greater electricity savings.

It is plausible to suggest that the high rate of electricity conservation in the FT relative to the PT and Control between September 2020 and December 2020 was due to a reflective workshop conducted with members of the FT group. This implies that, if users of electricity are involved not only in designing interventions but also in reflective processes on the effectiveness of the interventions, they can adjust electricity-use practices and respond to challenges of implementation. This explanation is supported by the evidence that households in the FT group felt their voices were included in designing electricity-saving interventions, and that the interventions were easy to implement. These results are consistent with principles of

transdisciplinary framing which argues that involvement of people in co-designing electricity-saving interventions can raise the level of concern needed to steer behaviour change (Ambole et al., 2020; Thondhlana et al., 2021). The two above-mentioned studies by Thondhlana et al. (2021) and Ambole et al. (2019) only proposed a basis for understanding transdisciplinary co-design processes. Results of this practical field-based study seem to confirm that stakeholder involvement based on a transdisciplinary process yields sustainable electricity use in low-income communities.

Interestingly, savings were also very high in the austral winter month of June 2020, which reflects the effectiveness of collective problem formulation and co-designed interventions in solving unsustainable electricity use. The persistent effect of interventions is also an indication that users now owned and felt their power in the project, consistent with the principles of co-designing, which states that collective interventions are easily accepted and long-lasting in solving environmental issues (Ambole et al., 2020; Thondhlana et al., 2021). Elsewhere, co-designed interventions have been tested effectively. For instance, a recent, similar study conducted in Monte Carlo resulted in average electricity savings of about 12% (Meng et al., 2020) while Cellina (2020) found a 20% average savings among Swiss households, further confirming the effectiveness of co-designed interventions in promoting electricity conservation. Though the savings recorded among Swiss households is higher than this study's savings of 14%, this must be considered in the context of the targeted households who are already marginalised and using comparatively less electricity than richer households, highlighting the importance of these co-designing processes in engendering savings.

4.4.2 Determinants of electricity consumption

The generalised linear regression model showed important insights salient in understanding household electricity consumption. The results showed counter-intuitive results in the relationship between household size and electricity reduction, consistent with Brandon and Lewis (1999) and Huang (2019), who found negative correlations between socio-demographic factors (including household size) and electricity consumption. However, consistent with findings elsewhere (McLoughlin et al., 2012; Williams et al., 2020), households with a high number of members between 6–17 years of age group were likely to consume more electricity. This might be explained by the fact that this age group often spend more time on activities that consume a lot of electricity,

including watching TV overnight and gaming (if uncontrolled) (Williams et al., 2020). In an Irish case study, McLoughlin et al. (2012) found that households with children and up to middle-aged adults consumed more electricity because of the number of people active during the night. It could also be argued that young members of households do not incur the costs of wasteful electricity practices, hence they might have less interest in saving electricity in the household (Trotta, 2018). Trotta (2018) reported that UK households with people aged 24 years and below had a lower chance (13%) of engaging in electricity-saving behaviour than households with members aged 25 years and above who had up to 55% chance of doing so.

Households with employed people reduced consumption possibly because they bear the costs of electricity use, so they are bound to minimise consumption to minimise costs related to electricity purchases. This is consistent with classical economic theories; for instance, the “labour theory of value” (Junankar, 1982; Peach, 1993) states that the economic value of a service is determined by the effort invested in acquiring it. Huang (2015) found similar results among Taiwanese households and argued that employed people may consume less electricity because of the limited time they spend at home and the economic cost associated with electricity consumption. Taken together, these results imply that consideration of socio-demographic variables is very important when crafting interventions for sustainable electricity use. For example, for interventions to be effective, they should target young to middle-age groups as well as the unemployed. For example, in 2010 the South African energy sector came up with Incline Block Tariff (IBT) intervention aimed at cushioning the unemployed, low-income, electrified households from continuous price increases (Department of Energy South Africa, 2012). The IBT allows the excess use of electricity to be billed on a sliding scale. However, although very useful, this initiative has been implemented by only 30% of the municipalities, thereby making it insignificant.

4.4.3 Relationship between electricity savings and psychological variables

The results showed that people who felt that their views were represented were likely to engage with the electricity-saving interventions. This suggests that involving people in interventions for sustainable electricity use is important because it can engender feelings of inclusiveness which can trigger the positive attitudes needed to change behaviour. Beckman et al. (2007) found that the involvement of employees in company design resulted in positive effects, and this approach has

become the widely used type of management intervention among big companies where it often results in employee satisfaction. Nevens et al. (2013), in research on co-creating sustainable cities, found the importance of collective problem formulation and co-designing of electricity-saving in promoting positive attitudes towards electricity-saving in Dutch cities. Mauser et al. (2013) also suggest that including civil societies in the discussions and crafting of interventions enables them to reflect on their ideas, which changes their attitudes positively. These sentiments align with the goals of transdisciplinary research to establish relationships and shared understanding for designing interventions that are relevant to society (Hirsch-Hadorn et al., 2008; Thondhlana et al., 2021).

Similarly, having control over one's situation yielded electricity savings in line with findings by Ru et al. (2018) among Chinese households. Ajzen (1991) suggests that high Perceived Behavioural Control boosts the intention to act positively, which results in pro-environmental behaviour. A positive correlation between the ease of electricity interventions and electricity savings also implies that the structure of interventions is an important determinant of whether people will perform the desired behaviour. This is comparable to Lin et al.'s (2021) study on the influence of Perceived Behavioural Control on marine responsible environmental behaviour. In the study, Lin et al. (2021) found that Perceived Behavioural Control helps people to evaluate how much effort they will need to perform a given task and whether they should persist in doing the task in the face of difficulties. In this study, it is possible that collective problem formulation with household participants helped households in the FT group to understand the sustainability challenge and interventions, and how they relate to their context, which empowered them to own the project. These results are comparable to Botetzagias et al. (2014) in a study of electricity curtailment behaviour who also found positive effects of Perceived Behavioural Control among Greek households. In the study, households that showed high levels of Perceived Behavioural Control recorded the highest electricity saving.

Results also showed a positive significant correlation between those with strong intentions to save electricity in the future and actual electricity saving. This implies that reflective workshops, collective problem formulation and collective intervention design could have empowered FT participants with valuable knowledge that changed their intentions to save electricity. This result

supports the findings by Kumar (2012) who found a positive correlation between discussions on environmental issues and the intention to purchase environmentally sustainable products. Findings by Wang et al. (2014) among Beijing residents similarly showed that households with strong intentions to save electricity saved more electricity than those with weak intentions. However, according to the Theory of Planned Behaviour (Ajzen, 1991), behaviour intention does not always translate into behaviour. For instance, in a study to understand the gap between environmental values and behaviour in Canada, Kennedy (2009) found negative correlations between behavioural intentions and behaviour, implying that the influence of intentions is not absolute.

Overall, the results advance our understanding of the effects of behavioural interventions in promoting electricity conservation in households. In particular, the results highlight the importance of active involvement of electricity users in designing interventions, including problem formulation, drafting of interventions, and reflective workshops on the experiences of implementing interventions in engendering a sense of inclusion, trust, having control over one's situation needed for triggering the intention to save electricity. These findings also imply that users make conscious decisions to realise electricity savings, and the extent to which such savings are realised depends on the constraints and opportunities surrounding daily household consumption. For instance, high levels of Perceived Behavioural Control and minimum levels of responsibility ascribed to performing electricity-saving behaviour are more likely to result in greater electricity savings.

4.5 Conclusions

The study investigated the effectiveness of co-designed interventions on electricity consumption among low-income households. Such an analysis is important in identifying context-specific and sustainable electricity-use interventions. Further, this study extends our understanding of the effectiveness of interventions by illustrating that electricity-saving behaviour can be sustained beyond the project lifespan, as demonstrated in this study, if co-designing forms the basis of identifying the sustainability challenge and, in turn, develops ways for addressing it. Concerning the interplays between electricity-saving behaviour and psychological factors, the findings suggest complexities in the sense that the relationships are not straightforward. Rather, various factors seem to interact in shaping behavioural outcomes, which points to the need for further studies on

the intersection of various factors and their effects on behaviour. The insights from this work are important but are based on a single study hence they are insufficient to leverage responsiveness from policy makers and related practitioners. Therefore, there is a need for further empirical studies on the subject to allow generalisations and conclusive judgements on the effects of co-designed interventions on promoting electricity conservation in households.

Chapter 5: Synthesis of findings and policy implications

5.1 Introduction

What is the current state of conceptual insights on household electricity-use research in South Africa? What is the reported electricity-use behaviour in households? What are the effects of different intervention strategies on reported household electricity-use behaviour and actual reduction in consumption? In what ways do knowledge co-production and co-design facilitate the transition to sustainable electricity use? Based on the findings, what are the implications of assumptions and constructs underlying pro-environmental behaviour, and practical implications for local level transition to sustainable electricity use? These are the questions addressed in this study. Chapter 2 focused on the state of research on household electricity use in South Africa. Chapter 3 examined electricity-use behaviour and various socio-demographic and psychological factors influencing pro-environmental behaviour among the low-income households in Makhandla, South Africa. Chapter 4 examined the effects of co-designed behavioural interventions on electricity use among low-income households.

5.2 Summary of findings

- The distribution of articles on household electricity-use behaviour showed a limited number of articles present from the period 2000–2020. Generally, findings showed limited literature focusing on household electricity-use behaviour and co-designing, with much of the literature focusing on technical interventions (Chapter 2).
- Households reported both good and bad electricity-use behaviour, and behaviour was influenced by socio-psychological factors including power, hedonism, and universalism (Chapter 3).
- Findings showed that co-designed interventions were the most effective in achieving electricity savings (Chapter 4).

5.3 The importance of household electricity-use literature and reported electricity-use behaviour in co-designing of interventions

Overall, findings showed that the research on household electricity use is still at its infancy in South Africa, when compared to literature from developed nations. This is probably because the

contribution of households to the country's carbon emission factor is fairly low, relative to other sectors such as the industry and the mining sectors, and hence it has been overlooked by research. However, the limited literature that is available has been mainly technical rather than behavioural. Additionally, there is no literature on interventions that are motivated by the need to involve the users of electricity in the design process of interventions, which makes interventions irrational and less acceptable to users. The limited literature is insufficient to inform interventions, hence it was evident from the results that most interventions had been externally initiated.

Furthermore, technical interventions are effective but cannot address wasteful behaviour, particularly among low-income households where there are limited financial resources to replace inefficient appliances with efficient ones. Hence there is a need for more work focusing on the integration of behavioural and technical interventions, as well as collaborations between policy drafters and end-users of electricity (co-designing) to inform the creation of such interventions. The costly nature of technical interventions implies that they may not be the best option, especially considering that low-income households have limited financial resources and that Eskom is experiencing a financial crisis. Behavioural interventions offer a cheaper, more sustainable option for household electricity saving. The dispersed nature of household electricity consumption makes it difficult to regulate with technical interventions, hence more work should be directed towards behavioural approaches. Broadly, the findings empirically validate the impact of collective problem formulation and co-designing interventions in promoting sustainable actions. Despite the dominance of literature on efficiency in South Africa, there is an absence of literature focusing on how households make choices in purchasing efficient appliances. The available literature on efficiency mainly focuses on making a comparison between energy labelled and non-energy labelled appliances. There is limited evidence of literature focusing on evaluating households' state of knowledge and awareness of efficient products. Therefore, future research should explore the extent of ownership of and levels of awareness about purchasing efficient household gadgets as this information is important in determining the type and level of intervention suitable for specific groups of the society.

Findings on the reported electricity-use behaviour showed that socio-demographic factors like age and gender, as well as people's values play a central role in determining electricity consumption.

This implies that, for service providers and policy drafters to come up with rational, practical, and effective interventions, they should focus on the users, as they provide a framework from which to structure interventions. Broadly speaking, interventions that are informed by the socio-psychological factors of the end users are likely to be more effective as users can easily relate to them. Thus, service providers are obligated to include the users of electricity in crafting interventions rather than the top-down interventions that have proved to be unsustainable (Eskom, 2020). Poor electricity-use behaviour relating to appliances which function in standby mode was also reported. Among well-resourced governments, such a result would provide a huge opportunity for savings, especially if governments, policy drafters, electricity service providers and manufacturing companies worked together towards minimising the amount of electricity used in standby mode. This could be done through introducing binding policies which encourage the manufacturing of appliances that automatically cut off power completely after a certain time they are left on standby mode which could save households from unnecessary electricity losses. However, one challenge that comes with such an initiative, in the South African context, is the issue of costs that come with such interventions, making behavioural interventions a cheap and sustainable pathway for promoting electricity conservation.

Findings also showed that electricity use was determined by socio-psychological value factors including universalism, hedonism, and power, implying that effective interventions should be informed by these value factors. Interestingly, the interpretation of values is different across contexts, which implies that service providers need to be cognisant of the contextual interpretation given to certain value factors and their influence on behaviour. Broadly speaking, this supports the fact that interventions that have been tested elsewhere (for example, in developed countries) might not be effective at a local level as such interventions were created for a totally different context. Hence, local users need to be key players in developing interventions rather than employing externally crafted interventions. Findings also illustrated that much work on electricity-saving interventions in the household was quite prescriptive and did not show the persistent effect of interventions as people often reverted to their old, wasteful behaviour. However, this study illustrates that the involvement of local communities or households in the design of interventions can lead to substantial electricity savings. Interestingly, electricity savings from this study were high even in the austral months of the year, adding weight to the effectiveness and the persistent

effects of co-designed interventions in reducing electricity consumption among low-income households.

5.4 Proposed conceptual framework

Drawing from the study results, a conceptual framework can be used to describe and explain the various determinants of pro-environmental behaviour. Figure 5.1 presents a framework developed from the findings of the study. The framework shows that household electricity-use literature from a local level is important in informing the co-designing of interventions. Therefore, there is a need for more research focusing on household electricity use and co-designing of interventions by local users. Determinants of electricity-use behaviour such as socio-demographic factors (age, gender, employment status etc.) and values are important in providing a framework from which to develop and structure interventions. In other words, this further justifies the collaboration of different actors in the electricity sector and household users in creating electricity-use interventions. Transdisciplinary processes go beyond a combination of different actors from various disciplines, and cut across people's culture, values, and socio-demographic characteristics. To achieve the best outcome in terms of electricity savings, researchers, electricity-service providers, and policy drafters and end users need to work together and acknowledge the importance of each other. The effectiveness of interventions is contextual and therefore should be informed by the local literature and socio-psychological factors.

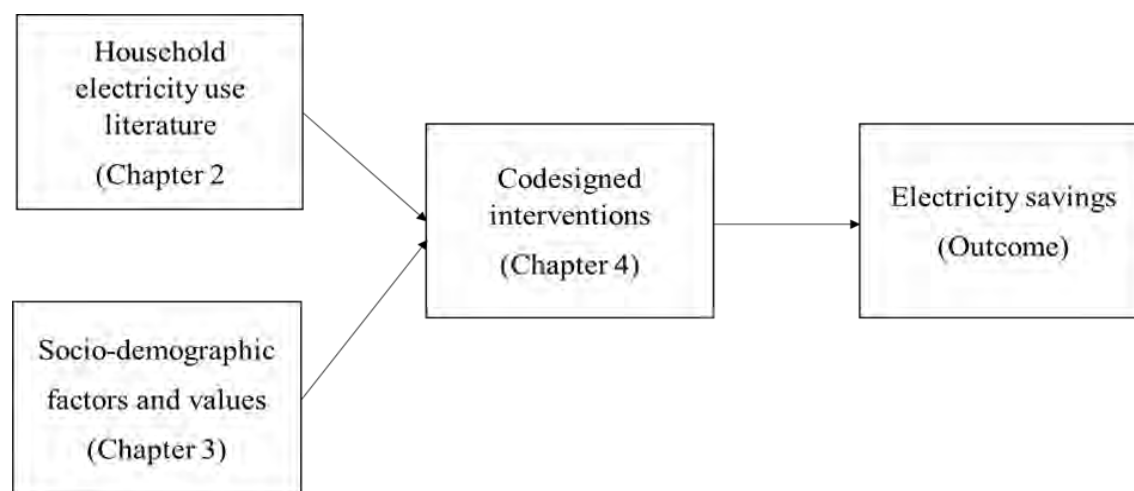


Figure 5.1 Framework for understanding the contribution of findings towards electricity saving

5.5. Conclusion

Studies on behavioural interventions for sustainable electricity use among households are not common in South Africa. Consequently, there is a need for more research which focuses on understanding electricity-use behaviour among households, to inform the co-designing of interventions for sustainable use rather than drawing on external literature which might result in irrelevant and irrational interventions. Therefore, the main aim of this work has been to provide conceptual and empirical insights from which the government, policy drafters, and users could develop an understanding of electricity-use behaviour among low-income households as a basis for co-designing interventions. The study has shown the connection that exists between literature, socio-demographic factors and electricity-use interventions which demonstrate the importance of more research on household electricity use in South Africa. The study has also shown that electricity consumption is determined by various socio-demographic factors, including age and employment status, as well as socio-psychological values such as universalism and hedonism. Results has also shown that co-designed interventions are most effective in reducing electricity consumption in households. The implication of these findings is that policy and intervention drafters need to be conscious of these factors as they contribute to the crafting of rational, effective, and long-lasting interventions.

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Appendix 3A

Table 1 Personal Value Orientations, Value Domains and High-Order Values

Personal Value Orientation	Value Domains	Higher-Order Values
1. Aesthetic beauty: being able to enjoy the beauty of nature and culture.	Universalism	Self-transcendence
2. Environmental quality: having access to clean air, water and soil. Having and maintaining a good environmental quality.		
3. Nature: enjoy natural landscapes and assurance of the continued existence of plants and animals.		
4. Social justice: having equal opportunities and rights as others.		
5. Social relations: having good relationships with friends, colleagues, neighbours.	Benevolence	Openness to change
6. Family: having a stable family life and good family relationships.		
7. Challenge/excitement: having challenges and experiencing pleasant and exciting things.	Stimulation	
8. Change: having a varied life, experiencing many things as possible.		
9. Freedom: freedom and control over the course of one’s life, to be able to decide for yourself, what you do, when and how.	Self-direction	
10. Private: having opportunities to be yourself and to do your own things.		
11. Identity: being able to develop one’s own identity.		
12. Comfort: having a comfortable and easy daily life	Hedonism	Self-enhancement
13. Leisure time: having enough time after work being able to spend this time satisfactorily.		
14. Education: having the chance to get a good education and to gain general knowledge.	Achievement	
14. Work: having or being able to find a job and being able to fulfil it as pleasantly as possible.		
15. Material beauty: having nice possessions in and around the house		
17. Money/income: having enough money to buy and to do the thing necessary and pleasing.	Power	Conservation
19. Social status: being appreciated and respected by others	Security	
20. Safety: being safe at home and in the streets		
21. Security: feeling attended to and cared for by others.		
Health: being in good health and access to adequate health care	Tradition	
22. Spirituality/religion: being able to live a life with an emphasis on spirituality and/or with your own religious persuasion.		

Appendix 3B

Table 2. Self-reported electricity-use practices. Double asterisk ** refers to inverse coding.

Electricity-Saving Action	Number of Respondents	Mean PEB Score	Modal Response	Percentages (%)
Keeping windows and doors closed when fan is on	56	3.5	Sometimes	36
Keeping windows and doors closed when heater is on	45	3.9	Always	64
Turning off microwave completely instead of leaving it on standby	151	3.2	Always	43
Matching pot sizes and hot plates on stove	179	3.9	Always	49
Defrosting refrigerator without automatic settings	135	2.6	Sometimes	43
Overloading the refrigerator	198	2.6	Sometimes	53
Cooling down hot food before storing in refrigerator	204	4.3	Always	67
Covering liquids stored in the refrigerator	204	4.5	Always	69
Taking all ingredients from the refrigerator at once when preparing food	204	3.2	Sometimes	40
Adjusting power setting according to weather condition	200	1.6	Never	71
Switching off the refrigerator when it is empty	193	2.2	Never	48
Boiling just enough coffee/tea water as you need	204	3.8	Always	44
Making use of daylight instead of lights during the day	207	4.3	Always	72
Turning lights off when nobody is in the room	207	3.8	Always	52
Using task lighting for activities requiring small amount of focus light (e.g., reading lamps)	196	1.4	Never	83
Turning off home appliances (TV, stereos, iPads, and satellite boxes) instead of leaving on standby	193	2.8	Never	33
Allowing computer to be on hibernation mode after 10–15 min	43	3.1	Sometimes	47
Switching off computer completely when not in use for more than 30 min	44	3.7	Always	39
Unplugging phone/iPad chargers after use	152	3.6	Always	43
Turning off geyser when not needed (e.g., overnight)	61	3.3	Always	46

Appendix 4A

Table 1. Effects of the interventions on electricity consumption.

Action		FT	PT
Sharing of Information			
shared to all members		60	36
shared to some		37.5	64
shared to none		2.5	-

	Number of people FT and PT	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Concerned						
You have changed your old ways of using electricity in your home	n= 40 n= 28			17.5 43	70 50	12.5 7
You are more concerned about wasting electricity than before	n= 38 n= 29			18 24	58 52	24 24
Motivation						
You save electricity so that you can save money	n= 40 n= 28			5 14	52 43	43 43
You save electricity so that you can save the environment	n= 39 n=26			13 31	67 46	20 23
You save electricity so that you can stop load shedding	n=38 n= 26			13 15	66 58	21 27
Encouragement makes me perform the recommended measures	n= 39 n= 28			8 25	74 64	18 11
You feel a sense of satisfaction after implementing measures	n=39 n= 28		7	28 46	54 36	18 11
Knowledge about the previous month saving encouraged you to implement interventions	n= 40 n= 27			22 22	60 56	18 22
Ability						
Electricity-saving measures are easy to do	n= 40 n= 28		10 21	40 43	40 32	10 4
Agency						
You feel involved in saving electricity in your home	n= 40 n= 28			20 43	58 46	22 11
The electricity champions are interested in hearing your views pertaining to electricity-saving interventions	n= 39 n= 28			5 4	67 85	28 11
You feel your views are represented in the electricity-saving intervene	n= 40 n= 28			18 36	67 60	15 4
You engaged in electricity saving because the information was from a trusted source	n= 40 n= 27			5 11	80 67	15 22

You will share your experiences with your friends' neighbours and relatives	n= 40 n= 28			5 29	53 46	42 25
As communities, we have the power to change our situation	n= 40 n= 28			8 14	62 61	30 25
Subjective norms If I save electricity, the people significant to me would	n= 39 n= 28			3 29	69 46	28 25
Electricity saving is the responsibility of everyone in the household	n= 40 n= 28			8 4	42 57	50 39
Perceived Behaviour Control How much control do you have over reducing consumption in your household	n=37 n= 25			32 48	38 36	30 16
How difficult is it for you to reduce consumption in your household	n= 38 n= 28	3 4	16 21	42 46	23 29	16
Is it my choice, whether I reduce household electricity consumption	n= 38 n= 28		4	32 39	55 53	13 4
Behavioural Intention My intention to save electricity in my home is	n= 40 n=27		10 -	12.5 33	52.5 41	25 26
How likely are you to save electricity in your home in the next months	n= 39 n= 26			21 42	46 35	33 23