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(Research Article)

Enhancing energy-saving behaviors of domestic electricity consumers in Zambia: A demand side management model

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Abstract

Climate change has affected the availability of water, reducing the levels of water for electricity generation, this has resulted into massive load shedding, considering that the region and Zambia in particular, is highly dependent on hydropower.

Literature suggests that that energy-serving behaviour has a huge potential to reduce energy demand drastically. Nevertheless, the switch and save campaign by Zesco, has not yielded much success, as load shedding is still being experienced despite the campaign. It is for this reason that this research was conducted to develop a demand side management model that will enhance the energy-saving behaviours of domestic electricity consumers.

This model is interactive and operates on the principle of information, encouraging the consumer to reduce the excess loads and instead use alternative sources particularly for heating and lighting. Where there is no compliance, the option by the system is to load-shed that particular consumer not complying with the requirements. It is believed the implementation of this system would persuade the domestic electricity consumers to use electricity prudently and reduce the chances of complete electricity black-out.

The discussion has also included global diverse energy forms which exist, and are used at various scales: global, regional, national, community and household level. Among these scales, the household level is considered as the terminal link for energy consumption and sustained environmental protection. It is worth noting that these concerns gave rise to an investigation on mechanisms on how to enhance energy saving behaviours of domestic electricity consumers in Zambia: a demand side management model. Although demand-side management (DSM) needs to be more customer centered, either with or without smart technologies for smart grid, less attention has been paid to the developing world in relation to DSM strategy development. The main reasons have been lacking appropriate technology and capital costs. Importantly, there are alternative DSM strategies that require minimum or no cost to implement and provide immediate results, of which energy-saving behaviour for the occupant at residences is one. The Model for Enhancing Energy Saving Behaviour (MEESB) is therefore a demand response technology and strategy, which applies the Time-based, Incentive-based and energy saving-behaviour programs to achieve energy conservation.

The study utilized a mixed research method employing both qualitative and quantitative in the research design. The findings of the study were that electrical practitioners agree with the idea of utilising a suitable demand side model that has features for warning the individual domestic householders of their drawing of electricity current beyond the limit set by the supply authority. They are also in agreement that load shedding should only be implemented to electricity consumers who do not comply with the appeal to "switch and save power". Finally, the electrical practitioners agree with the idea of a provision within the model for enhancing energy saving behaviours, for resetting back to supply, upon isolating the loads consuming excess power, if the household was load shaded for exceeding the set limit of electricity

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consumption. The study established that domestic electricity consumers have sufficient knowledge of electricity saving technology and its benefits in matters of steady supply of electricity.

Keywords: Appropriate; Develop; Energy-Saving Behaviour; Enhance; Model; Demand-Side Management

1. Introduction

Globally, energy conservation is a subject that has continued to attract global debate and attention, more especially after the 1990s when climate change topics were at peak (Malama *et al.* 2015), and more so as the demand for energy and natural resources has been increasing rapidly in conjunction with rising population, industrialization, and urbanization as well as the growth in production and commercial opportunities resulting from globalization. The primary goal regarding the climate change model is to understand the effect of the changes (Zhang, 2020). Since a significant amount of climate change is now essentially inevitable, adaptation in developing countries is critical for protecting livelihoods and continuing to make development gains. The discussion about energy conservation has included global diverse energy forms which exist, and are used at various scales: global, regional, national, community and household levels. Among these scales, the household level is considered as the terminal link between energy consumption and sustained environmental protection (Liu*et al.* 2021).

Household energy conservation also remains a key factor in meeting social economic needs and alleviating the energy deficit experienced in the African continent due to the rising population and under-developed energy systems. Over 620 million people, almost two-thirds of Africans, do not have access to electricity and nearly 730 million rely on traditional solid biomass for cooking (Ahmad, 2021). Those who do not have access rely on a very expensive, low-quality energy supply (Toshpulatov*et al.* 2020) quoting the World Bank and IEA (2015), further reports that, Sub-Saharan Africa lags behind all other regions of the world in household access to electricity, per capita power consumption, and installed generation capacity. This is even though energy resources are more than sufficient to meet energy demands. Meeting the increasing energy demand of the growing population and ensuring universal access to modern energy services with respect to the environment are, thus, the principal goals of African countries. To this end, energy management strategies are expected to ensure that energy supply-demand-related policies and investment decisions considers all feasible demand and supply-side options which are consistent with global goals of sustainability (Diaz *et al.* 2020). The SADC region enjoyed surplus electricity-generation capacity for many years. Despite the warning by the Southern African Power Pool (SAPP) as far back as in 1999, that the region would run out of generation surplus capacity by 2007 unless new investments in the energy sector were put in place, not much generation and transmission investment was auctioned to alleviate the anticipated generation capacity shortfall, resulting in electricity demand outstripping supply in 2007, as per the SAPP forecast.

Zambia is one of the developing countries in the SADC region, which is currently experiencing severe shortages of electrical energy, with extensive load shedding being implemented to address the supply-demand imbalance. This crisis has been experienced from time to time. At Itezhi-Tezhi only 70% of required water levels have been achieved yet when the rainfall is normal, the 100% levels of water required for generation is achieved by April. It is therefore evident that load shedding on a wider scale could be on the horizon".

The year 2019 was not spared. It also experienced critical power crisis, so much that the Times of Zambia on 22nd March 2019, under a heading Kariba dam power generation to drop 40p.c, reported by Brian Hatyoka, quoting Zambezi River Authority (ZRA) public relations and communications manager Elizabeth Karonga, stated that "Power generation at Kariba dam will reduce by about 40 per cent this year due to reduced water levels. It was further stated that the reduction in water levels would reduce the combined power generation level at Kariba from the current 1,476 megawatts (MW) to 890 MW." Zambia alone was to lose 293 MW of power supply. Further, the deficit has been exacerbated by the effects of climate change on the availability of water, considering that Zambia is highly dependent on hydropower. As a result, ZESCO Limited therefore embarked on a nationwide load shedding programmed in which power was cut to customers, particularly during periods of peak demand, for duration ranging from eight to fourteen hours per day, as a means of managing the electrical connected loads. In her short statement, ZESCO Senior Manager Marketing and Public Relations Bessie Banda said the firm has been forced to resume more load shedding due to reduction in generation at Kafue Gorge Power Station from an average of 700 MW to 600 MW because of low water levels.

To ensure continuity of supply, ZESCO Limited, whose mission statement is; "making it easy for people to live a better life", has urged its domestic customers to employ "energy saving techniques" such as the use of energy saving lamps for lighting, the use of low-pressure gas for heating as an alternative source of energy where possible. The findings in the report by the Living Conditions Monitoring Survey of 2015, shows that electricity is the primary clean cooking solution in Zambia, with 16% of households nationally cooking with electricity, increasing to 34% in urban areas and 41% in Lusaka. This dependency on electricity as a cooking solution in Zambia is blamed for high levels of demand, particularly at peak hour (19:00) when most households are cooking dinner. Furthermore, the government of Zambia has embarked on a policy of reducing the use of electricity for cooking from 35% to 20%, and to increase the use of LPG from negligible levels to 40% of households, to mitigate for high levels of demand, particularly at peak time and alleviate load shedding. (The Republic of Zambia Ministry of Energy, 2019). These are some of the demand side strategies ZESCO Limited is employing for addressing the challenge facing the reliable supply of electricity to domestic consumers in the Republic of Zambia.

Household conservation in Zambia, is vital in meeting the increasing energy demand largely consumed by the mining sector (51.1%) followed by household consumption (33.2%) (MoE, 2020). For instance, Vision 2030 describes an ambitious vision of universal access to clean, reliable and affordable energy at the lowest total economic, financial, social and environmental cost consistent with national development goals by 2030. It is thus essential that a study to determine an appropriate demand-side management model for enhancing energy saving behaviours of domestic electricity consumers, in order to address the challenge facing the reliable supply of electricity in Zambia be undertaken.

1.1. Statement of the Problem

Zambia is one of the developing countries in the SADC region which has been facing a serious electricity deficit because of the recurring low water levels at Itezhi-tezhi reservoir and Kariba dam as a result of the shortened period of rainfall seasons. To mitigate this power deficit and ensure continuity of supply and safety of infrastructure, ZESCO Limited has urged its domestic customers to employ energy saving techniques such as the use of low-pressure gas for heating, the use of energy saving lamps for lighting, and other alternative sources of energy where possible, as one of the demand side management strategies for addressing the challenge facing the reliable supply of electricity in the Republic of Zambia. It is meant to manage residential electricity demand, and when effectively implemented, it can be used to ensure the reliability of the electricity network, security of supply, and maintaining a good balance between supply and demand of the electricity system of any country (Halbrügge *et al.* 2021). The "Switch, Save and Share" campaign is a demand response strategy based on energy-use behaviour change. Sadly, at the household level, there is a lack of a national energy efficiency policy (Mwamba *et al.* 2020), and failure by domestic electricity consumers to comply with this call to switch and save, has resulted into ZESCO Limited to resorting and embarking on nationwide load shedding programmed, in which power supply to consumers is cut, particularly during periods of peak demand, for durations ranging from eight to fourteen hours per day, as a means of managing the electrical connected loads and safeguarding the infrastructure.

However, load shedding as an emergency response strategy for managing excess electricity demand, has its own challenges. Although this strategy is easy to implement and is effective from the side of the supply authority, it has its own disadvantages on the part of the consumers. To start with, it is not selective, as it affects both, those consumers who do not comply, and unfortunately, even those who comply with the call to implement energy saving measures. Not only that, the load shedding system operates on a binary basis. It is either there is full supply or there is completely no supply. Load shedding as an emergency response strategy does not provide for supply somewhere between completely no supply and maximum supply. As a result, many domestic and small and medium enterprises activities that depend on electricity supply and that do not necessarily draw so much power are choked and disrupted. This thereby affects the economy at domestic level. The study on Impact of Load Shedding on Small Scale Enterprises by the Energy Regulation Board, it was established that, the resultant power deficit of between 560 to 1000 MW resulted in load shedding of up to 8 hours. The incidence of load shedding in 2015 led to adverse disruptions in the operations of most of the small enterprises in the survey areas, affecting the most business operations and financial viability. The small enterprises were the most affected mainly due to their lack of resilience and limited capacity to invest in alternative energy sources.

Furthermore, most small enterprises had inadequate response strategies as they could not use alternative sources of energy. Some enterprises suffered losses due to equipment damage and high replacement costs (Du *et al.* 2020). Most small enterprises resorted to reducing their work outputs resulting in reduced turnover whilst incurring additional costs such as idle labour and overtime. Therefore, what remains is to analyse the various strategies that have been used to manage the electricity demand in Zambia and other countries, and thereafter, determine an appropriate demand-side management model that would enhance the energy saving behaviours of domestic electricity consumers, in order to realize the objective of ZESCO's campaign to "switch, save and share". If an appropriate demand side management model to correct the low compliance of domestic consumers towards electricity saving behaviour appeals, remains undetermined, Zesco will continue to use load shedding as a strategy for managing excess electricity demands, and regrettably the domestic consumers will continue to be affected negatively. This research is therefore, aimed at determining an appropriate Demand Side Management (DSM) model that can enhance electricity saving behaviours of domestic electricity consumers in addressing the challenge facing the reliable supply of electricity in Zambia.

1.2. Research Specific Objectives

- To identify demand side management models for managing domestic electricity consumption.
- To analyse characteristics of various demand side management models for managing domestic electricity consumption
- To develop an appropriate demand side management model for enhancing energy saving behaviour of domestic electricity consumers.

2. Literature review

2.1. Demands-Side Management

Demand-side management provides opportunities to achieve energy efficiency and reduce peak demand, which can lower system costs. DSM can provide many benefits, including peak demand reduction, enhanced reliability, market participating reserves, and flexibility to support renewable generation integration. It can also have the potential to help alleviate load shedding, which is a last-resort DSM mechanism. Demand response can be dispatchable and non-dispatchable, with options to implement programs in the retail or wholesale market (Binyet *et al.* 2022). DSM covers various grams in, including demand response, energy efficiency, and distributed generation.

2.2. Energy Efficiency Improvement

The energy efficiency improvement strategy might be the improvement of the efficiency of different electrical home appliances for the residential home.

2.2.1. Energy Efficiency in Buildings

The International Energy Agency (IEA) statistics estimate that the building sector is responsible for more electricity consumption globally than any other sector, 42 percent (IEA, 2004). The measures to improve energy efficiency in buildings lowers energy costs and reduces the amount of energy consumed while maintaining or improving the quality of services provided in the building (UNIDO, 2021). Investments in energy efficiency in a building can be compared with the cost of capital investments necessary on the supply side of the energy system to produce a similar amount of peak capacity or annual energy production.

2.2.2. The Concept of Energy efficiency in a Building

The energy efficiency of a building is the extent to which the energy consumption per square meter of floor area of the building measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions. In a typical energy flow in a building, the gross energy needs represent the anticipated building's requirements for heating, lighting, cooling, ventilation, air conditioning and humidification. The indoor climate requirements, outdoor climatic conditions and the building properties (surface/transmission heat transfer and heat transfer due to air leakage) are the parameters used for determining what the gross energy needs of the building will be. Natural energy gains include passive cooling, natural ventilation flow, and daylight. Internal heat is the thermal energy from people, lighting and appliances that give off heat to the indoor environment. Delivered energy is the amount of energy supplied to meet a building's net energy demand i.e. to provide energy for heating, cooling, ventilation, hot water and lighting. It is usually expressed in kilowatt hour (kWh) and electricity is the main energy carrier as well as fuels. System losses result from the inefficiencies in transporting and converting the delivered energy used to provide the actual services, e.g. lighting, cooling or ventilation, due to the inefficiency of the equipment used. (UNIDO, 2021). Electricity suppliers can influence the redistribution of the demand and time of electricity usage by load management by their customers.

2.2.3. Policy on Energy Efficiency in Buildings

To ensure effective implementation of energy efficiency in building involves the development and formulation of an energy efficiency policy and the enactment of a legal and administrative framework. The most effective programs are designed not only to ensure that a particular target level of energy efficiency improvement is realized but also to assure that the market is prepared continually to introduce better and better technologies for energy efficiency (UNIDO, 2021). Legislative and poly options that have had some record of success in promoting energy efficiency in buildings include the codes and standards (Sendrayaperumal *et al.* 2021)for new construction and performance-based economic incentives to go beyond the standards; long-term incentives with ambitious energy efficiency targets; normative labels to distinguish the most energy-efficient building and equipment; informative label that provides the information necessary to measure energy efficiency and annual energy costs for operations; education and outreach to promote market acceptance of energy efficiency technologies and energy-efficient designs; government-funded research and development on energy-efficient buildings.

2.2.4. Cases of Development and Implementation of Energy Efficiency in Building

Energy efficiency buildings policy was implemented in the State of California in the United States of America. Its implementation yielded many successes. Homes and commercial buildings consume 66% of the State's electricity. California's homes and buildings are relatively energy-efficient today, compared to those in other states and many countries of the world. Since the passage of the Warren-Alquist Act in 1975, homes and buildings in California have been made increasingly efficient, due to periodically updated efficiency requirements in Building and Appliance Standards. In this same 30-year period, the California Public Utility Commission has directed the investor-owned utilities to commit over $US 5 billion to energy efficiency information, technical assistance and incentive programs, an estimated 85 per cent of which has been targeted at retrofit energy efficiency investments in existing buildings. There are over 13 million existing buildings in California, compared to the approximately 200,000 constructed each year (Webb and McConnell, 2023). More than half of the existing buildings were built before the first Energy Efficiency Standards were established in 1978. While many have been upgraded over time, these older buildings represent a large reserve of potential energy and peak demand savings.

The Government of Victoria in Australia developed the Sustainable Energy Authority, an agency established to promote energy efficiency and support and facilitate the development and use of renewable energy in order to implement a greenhouse gas reduction strategy. Its aim is to achieve environmental and economic benefits for the Victorian community. The Sustainable Energy Authority of Victoria (SEAV) has established Energy Smart Advisory Centres that provide a range of information products to assist all sectors of the community to design and construct energy smart buildings. The SEAV also assists to select energy smart appliances; reduce energy costs through energy saving practices; and utilize renewable energy. They also distribute independent advice and information, media campaigns, seminars and targeted promotions. The Energy Smart Housing program aims to facilitate house energy ratings as the energy efficiency benchmark for housing and the introduction of energy performance standards. Activities include development of the First-Rate house energy rating software, provision of user training and accreditation of third-party rating providers. It includes Energy Smart Builders and Energy Smart Commercial Buildings (Farzaneh *et al.* 2021), which use the Building Greenhouse Rating scheme. Among the other In South Africa, the project of improving energy efficiency in Ekurhuleni Metropolitan Municipal (EMM) buildings started in June 2005 with the call on all suitably qualified entities to submit quotations to carry out all the necessary work to achieve the set objective of saving energy and reducing GHG emissions.

The first proposal included the supply, delivery and installation of solar water heaters, compressors and 10 KW solar photovoltaic panels. A preliminary analysis of a building's infrastructure, design and plumbing systems determined that the installation of solar energy would add more complexity and time to the work. The retrofitting project was to be completed before the end of the municipal financial year. The second proposal was the use of different mechanisms to reduce energy consumption in lighting and heating/boiling water. The mechanisms included the replacement of conventional incandescent lights with compact fluorescent light bulbs (CFLs), the replacement of cool-beam down lights with light-emitting diodes (LED) lights, the replacement of urns and kettles with hydro boils, and the installation of geyser and lighting timers. These measures were determined to be more cost effective and could be implemented within the set time frames and allow significant reductions.

A small-scale retrofit project, such as the EMM's buildings project, results in 328,988 kWh of energy saved in one year, representing economic savings in the order of $US 50,664 per year (using the value of $US 0.157/kWh for Ekurhuleni Municipal Buildings). In Zambia, the Energy Efficiency in Buildings program was implemented by the electricity supply utility company (ZESCO). It did so by using energy saving lamps for lighting. The Daily Mail of Zambia of July 25th, 2014, reported that ZESCO had embarked on an initiative in which it saved over 85 megawatts of electricity through the door-to-door distribution of over 1, 620, 000 compact lamps (CFL), and this enabled ZESCO to reduce domestic electricity consumption in Central Province. Besides that, ZESCO managed to implement the Solar Geysers Project on rooftops of domestic electricity consumers. The project managed to free the national grid of 150 MW of electricity. This study has considered the use of solar geysers as an alternative source of heating water, and energy saver bulbs as a strategy to replace high energy consuming incandescent lamps.

2.3. Energy Conservation

The energy conservation, which is a general term referring to the effort made to reduce the consumption of energy by using less of an energy service. This can be achieved either by using energy more efficiently (using less energy for a constant service) or by reducing the amount of service used. Globally, a number of studies such as the one done by Wei and Jones (2015), Frederiks *et al*. (2015), Zhou and Yang (2016), Fujimi *et al.* (2016) and Das Gupta (2011), have been conducted on household energy conservation practices as it has continued to attract global debate and attention. Among these, the study conducted by Zhou and Yand (2016) specifically was undertaken to understand household energy consumption behaviour as an effective way of improving energy efficiency and promoting energy conservation. This study has adopted the three factors of BJ Fogg' behavioural model: motivation, ability and triggers and the Reinforcement Theory of Motivation, by B.F. Skinner to develop an appropriate model for enhancing energy saving behaviour of domestic electricity consumers.

The study by Fujimi *et al*. (2016), indicates that household energy conservation can be enhanced through effective energy policies. They add on to note that factors of residents' psychological characteristics and intentions for energy consumption are traditionally important factors to formulate effective energy policies. This study will use the findings by Fujimi *et al,* (2016), to make recommendations for formulating policies on implementing the model for enhancing energy saving behaviour of domestic electricity consumers.

Das Gupta (2011) revealed that the major hints in promoting a sense of efficiency in energy utilization among householders are lack of information and awareness by households and lack of monitoring and regulation by relevant authorities. Like Das Gupta (2011), this study will determine how to provide timely information and awareness to house holders as a trigger to initiate the expected energy saving behaviour, in line with Fogg's behaviour model.

2.4. Demand Response

Generally, demand response strategy can be divided into two categories: time-based programs and incentive-based programs (Torriti, 2016). For the purpose of this study, we will include energy-saving behaviours, as one of the demand response strategies.

2.4.1. Time-Based Response

Time-based programs are designed to involve consumers in controlling electricity consumption during peak hours and gain benefits from it (Paramati *et al.* 2022). Using low power consumed items and reducing wastage of the power can be useful.

Time of Use Rate

Time of use (TOU), where utilities have different charges for power use during different periods, is one of the important demand side response programs, which responds to the price and is expected to change the shape of the demand curve (Na *et al.* 2006). Further, TOU rate is the most obvious strategy developed for the management of the peak demand in the world, which is designed to encourage the consumer to modify the pattern of electricity usage (Wen-Chen *et al.* 2007). For applying this program, the utility does not provide reward or penalty to consumers. To participate, all consumers are required to remove their energy consumption during peak session to off-peak session as soon as they receive information from the utility.

Real Time Pricing

Real time pricing (RTP) program pricing, where the rate varies based on the utility's load (continuously or by hourly), allows the consumers to access hourly electricity prices that are based on wholesale market prices. Higher prices are most likely to occur on peak session time (e.g. 05.00 PM – 09.00 PM). The consumer can manage the costs with real-time pricing by taking advantage of lower priced hours and conserving electricity during hours when prices are higher (Federal Energy Regulatory Commission, 2006). The evidence from an IHS Cambridge Energy Research Associates study, which draws on the knowledge and experience of those closest to smart grid implementation, is that the deployment of Smart grid technology, presents consumers with real-time power prices and displays of information regarding power use by specific end uses.

These price signals and information streams will empower consumers to have more control over their power consumption. Congress, in the Energy Policy Act of 2005, encouraged state regulators and utilities to shift from fixed rates to time-varied electric rates in order to increase energy efficiency and demand response. The study shows that, despite the benefits of real-time power pricing, most consumers focus on their pocketbook rather than the theoretical basis of this supposedly more efficient pricing system. This is compounded by the prospect of real-time pricing involving higher and more unpredictable prices; on an hour-to-hour basis, and the marginal cost of electricity being hard to predict and can change by a factor of 100 during any given day. Research clearly indicates that most consumers far prefer the stable and predictable power pricing schemes they currently have. Inside this study, the model will focus on the strategy that requires little or no investment on the part of the consumers to implement energy saving.

As real-time power prices are usually higher than traditional rates during peak periods and lower during off-peak periods, most consumers use more electricity during peak periods than during off-peak periods. This, therefore means that, unless the consumers can shift enough of their power use, they face a higher bill with a move to real-time pricing.

Participation in almost all dynamic pricing programs in the United States has been voluntary. Currently, time-of-use rates are offered by more than half of investor-owned utilities. Many of these programs have been offered for years, and in some cases decades. The average participation rate in such programs is estimated at 1%. Participation in programs in Illinois is typical. Commonwealth Edison ran a residential real-time pricing pilot program from 2003 to 2006, and for the past four years has made it available to all of its residential consumers.

Arizona provides an example of how the characteristics of the customer base affect the outcomes. Consumers there tend to be more electric-intensive because of above-average cooling loads. In addition, the nature of these loads provides greater-than-average flexibility in the time pattern of electric use and thus a higher-than-average probability that shifting power use could lower a consumer power bill. The Salt River Project and Arizona Public Service (APS) have about half of their customers on a dynamic pricing scheme. APS offers four time-of-use rates to customers. A 2010 analysis of two of the rates indicated that customers saved 21% on their electricity bills as compared to being on a flat rate. The same economic logic that helps to understand the Arizona versus Illinois results also applies to non-residential consumers.

2.4.2. Incentive-Based Response

Incentive-based programmes are dealt with by electricity companies and provide incentives to consumers (Paramati *et al.* 2022). This plan encourages the consumers to be more alert in the energy conservation process.

Tariff Incentives and Penalties

Electricity suppliers can influence the redistribution of the demand and time of electricity usage by load management by their customers (UNIDO, 2021). Incentives, both rewards and punishments, are among the instruments that have been embedded in electricity product designs to reduce consumptions (Jasmin *et al.* 2020). Utilities encourage a certain pattern of use by tariff incentives where customers use energy at certain times to achieve a better-priced rate for their energy use. Time-base programmes and incentive-based programmes are types of demand response strategy. Time-based programmes are designed to involve consumers in controlling electricity consumption during peak hours and gain benefit from it, whereas incentive-based programmes are dealt by electricity companies and provide incentives to consumers. On the other hand, common incentive-based programmes include Interruptible or Curtailable rate and Emergency Demand Response programme (Paramati *et al.* 2022).

Interruptible/Curtailable program

Interruptible/curtailable program has traditionally been one of the most common DSR models used by electric-power utilities. In this program consumers sign an interruptible-load contract with the utility to reduce their demand at a fixed time during the system's peak-load period or at any time requested by the utility (Yu, 2005). This service provides incentives/rewards to consumers participating to curtail electricity demand. The electricity provider sends directives to the consumers for following this program at certain times. The consumers must obey those directives to curtail their electricity when being notified from the utility or face penalties.

Emergency demand response program

Emergency Demand Response Program (EDRP) is an energy-efficient program that provides incentives to consumers who can reduce electricity usage for a certain time; this is usually conducted at the time of limited availability of electricity. EDRP provides participants with significant incentives to reduce load (Covino, 2003). This program will determine which houses must be included in the event to minimize cost and disruption, while alleviating the overload condition (Tyagi, 2010) when asked to curtail, and verified to have performed, the consumer is paid. To participate in this program, all consumers are expected to reduce energy consumption during the events.

Power Factor Charges

Power factor charges are applied where users are penalized for having power factors below a fixed threshold, usually 0.90 or 0.95. When the power factor is less than unity, the amount of useful power supplied by the generating plant at maximum output will be less than its full capacity (in other words, when the PF is less than one not all the power supplied is turned into useful work). This represents an inefficiency and therefore utility companies usually require customers to achieve a power factor of at least 0.9 (sometimes 0.95). Those who fail to meet the minimum required value will be charged a penalty on their bills to compensate for the various losses incurred by the generator (e.g. losses in distribution cables and transformers). Power factor charges, where the rate varies based on the utility's load.

The migration towards cost reflective tariffs is seen by many as a remedy to the challenges facing the Electricity Supply Industry in Zambia, such as the power crisis of 2015, which revealed that the industry has failed to attract the envisaged private sector investment required to expand and diversify energy generation sources and meet the increasing demand for electricity over the years (Mwanda, 2018). A cost-reflective tariff is defined as one that ensures recovery of all the allowable costs of each regulated and licensed activity within the generation, transmission, distribution and supply value chain and also ensures a reasonable rate of return on investment (Sikwanda, 2016). In Zambia, the Revenue Requirement Methodology (also known as the rate of Return) is used by the Energy Regulation Board (ERB) to compute electricity tariffs. Operating and maintenance expenses, taxes and depreciation, and a fair rate of return on assets utilized in the generation, transmission, distribution and supply of electricity are the main considerations in determining the tariffs (ERB 2018). Notwithstanding this criterion, the Cost-of-Service study conducted in 2006 established that Zambia's tariffs were below cost for all consumer categories. For one, this reveals that the Government of Zambia had been subsidizing electricity for a number of years, and this implies that utilities have not been able to recoup the full costs of supplying electricity to consumers. Notably, between the years 2008 and 2014, ZESCO sought tariff adjustments to increase tariffs towards cost reflectivity. However, this was not fully achieved. The tariff at which electricity is sold directly to consumers through bilateral contracts is therefore a major barrier to entry in the supply segment of the value chain and consequently a factor that limits competition despite market liberalization. Mwanda and Ziba 2018 Investment Challenges in Zambia's Electricity Supply Industry: A Cursory Assessment (Zambia Institute for Policy Analysis and Research).

Renewable feed-In Tariff

Renewable Feed-In Tariff (REFIT) is a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers (Cory *et al*. 2010). Feed-in tariffs (FITs) are the most widely used policy in the world for accelerating renewable energy (RE) deployment, accounting for a greater share of RE development than either tax incentives or renewable portfolio standard (RPS) policies (REN21 2009). Their goal is to offer cost-based compensation to renewable energy producers, providing price certainty and long-term contracts that help finance renewable energy investments (Couture, *et al.* 2010). Typically, FITs award different prices to different sources of renewable energy in order to encourage development of one technology over another. For example, technologies such as wind power and solar PV, are awarded a higher price per kWh than tidal power (Kaunda *et al.* 2014). FITs often include a "digression", a gradual decrease of the price or tariff, in order to follow (Couture *et al.* 2010) and encourage technological cost reductions. Under a feed-in tariff, eligible renewable electricity generators, including homeowners, business owners, farmers and private investors, are paid a cost-based price for the renewable electricity they supply to the grid. This enables diverse technologies (wind, solar, biogas, etc.) to be developed and provides investors a reasonable return. FITs typically include the following three key provisions; guaranteed grid access; long-term contracts; and cost-based purchase prices (Mendonça, 2007).FITs have generated significant RE deployment, helping bring the countries that have implemented them successfully to the forefront of the global RE industry. In the European Union (EU), FIT policies have led to the deployment of more than 15,000 MW of solar photovoltaic (PV) power and more than 55,000 MW of wind power between 2000 and the end of 20091 (EPIA 2010, GWEC 2010). In total, FITs are responsible for approximately 75% of global PV and 45% of global wind deployment (Deutsche Bank, 2010).

This principle in Germany's 2000 Renewable Energy Sources Act, explains the application of compensation rates, and how they have been determined by means of scientific studies subject to the provision that the rates identified should make it possible for an installation – when managed efficiently – to be operated cost-effectively, based on the use of state-of-the-art technology and depending on the renewable energy sources naturally available in a given geographical environment. As a result, the tariff (or rate) may differ by technology, location (e.g. rooftop or ground-mounted for solar PV projects), size (residential or commercial scale) and region (Couture *et al.* 2010). The tariffs are typically designed to decline over time to track and encourage technological change (Couture and Gagnon, 2010). FITs typically offer a guaranteed purchase agreement for long (15–25-year) periods (Lipp and Judith 2007). Performance-based rates give incentives to producers to maximize the output and efficiency of their project (Klein *et al.* 2008). 2008, the European

Commission by means of a detailed analysis concluded that "well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity" (European Commission 2008). This conclusion was supported by other analyses, including by the International Energy Agency (2008), the European Federation for Renewable Energy (2007), as well as by Deutsche Bank. (EREF 2007).

As of 2019, feed-in tariff policies had been enacted in over 50 countries, including Algeria, Australia, Austria, Belgium, Brazil, Canada, China, Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iran, Republic of Ireland, Israel, Italy, Kenya, the Republic of Korea, Lithuania, Luxembourg, the Netherlands, Malta, Pakistan, Portugal, South Africa, Spain, Switzerland, Tanzania, Thailand, Turkey and the United Kingdom (REN21, 2021)

Countries such as Germany, in particular, have demonstrated that FITs can be used as a powerful policy tool to drive redeployment and help meet combined energy security and emissions reductions objectives (Germany BMU, 2007). First introduced in 2000, the Renewable Energy Sources Act (German: Erneuerbare-Energien-Gesetz) is reviewed on a regular basis. Its predecessor was the 1991 Storm EinspeiseGesetz. As of May 2008, the cost of the program added about €1.01 (US$1.69) to each monthly residential electric bill (Lander and Mark 2008). In 2012 the costs rose to €0.03592/kWh (2012 EEG surcharge increases slightly to 3.592 ¢/kWh". (German Energy Blog, 14 October 2011).

The Egyptian Ministry of Electricity on 20 September 2014, announced the new feed-in tariff (FIT) pricing for electricity generated from new and renewable energy sources for households and private sector companies (Daily News Egypt - 20 September,2014). The FIT will be applied in two phases, the official date for applying the first phase is 27 October 2014 and the second phase to be applied after two years from the first phase (which was launched on 28 October 2016). The Egyptian Feed-In Tariff Programme Update on 06 September 2016 reported that the energy tariff during the first phase has been divided into five categories; the purchase price per kilowatt-hour (KWh) for residential solar generation is EGP 0.848. For non-residential installations of less than 200 kilowatts of installed generation capacity, the price rises to 0.901 EGP/KWh. The third category, between 200 and 500 kilowatts, will be paid 0.973 EGP/KWh. The fourth and fifth categories of non-residential installations are paid in USD, to attract foreign investments, with the fourth category, ranging from 500 kilowatts to 20 megawatts, paid US$0.136/KWh (with 15% of tariff pegged at the exchange rate of 7.15 EGP per USD). The last category, which stretches between 20 to 50 MW, will be paid US$0.1434/KWh. On the other hand, the purchase price for power generated from wind is based on the number of operating hours and is more elaborate than the solar tariff. It covers operating hours ranging from 2500 up through 4000 hours, with decreasing purchase rates ranging from US$0.1148/KWh down to US$0.046/KWh.

While in the second phase, the categories of solar generation were reduced to four, with the residential category tariff increased to 1.0288 EGP/KWh. The second category, non-residential installations of less than 500 KW has a purchase price of 1.0858 EGP/KWh. The third and fourth categories, non-residential installations between 500 KW and 20 MW and between 20 MW and 50 MW, have a purchase tariff of US$0.0788/KWh and US$0.084/KWh, respectively (with 30% of tariff pegged at the exchange rate of 8.88 EGP per USD). The government will purchase the electricity generated by investors, taking inflation into account, while consumption will be paid in local currency and depreciation rates will be reviewed after two years. The Ministry of Finance will provide concessional subsidized bank financing for households and institutions using less than 200 KW at a rate of 4%, and 8% for 200-500 KW. The government is preparing a law that would allow for state-owned lands to be made available for new energy production projects under a usufruct system in exchange for 2% of the energy produced. The electricity companies will be obligated to purchase and transport the energy. The new tariff system also includes a reduction in customs on new and renewable energy production supplies by 2% while the proportion of bank financing has been set at 40–60%. The government hopes for new and renewable energy to account for 20% Egypt's total energy mix by 2020 (Egyptian Electricity Holding Company Annual Report 2011/2012).

In South Africa, the Western Cape Province is allowing feed it tariffs as of 2022. The National Energy Regulator of South Africa (NERSA) announced 31 March 2009 a system of feed-in tariffs designed to produce 10 TWh of electricity per year by 2013. The tariffs were substantially higher than those in NERSA's original proposal. The tariffs, differentiated by technology, were to be paid for 20 years. NERSA said in its release that the tariffs were based on the cost of generation plus a reasonable profit. The tariffs for wind energy and concentrating solar power were among the most attractive worldwide. The tariff for wind energy, 1.25 ZAR/kWh (€0.104/kWh) was greater than that offered in Germany and more than proposed in Ontario, Canada. The tariff for concentrating solar, 2.10 ZAR/kWh, was less than that in Spain. NERSA's revised program followed extensive public consultation. Following NERSA's announcement of the feed-in tariffs, Stefan Gsänger, Secretary General of the World Wind Energy Association said that "South Africa is the first African country to introduce a feed-in tariff for wind energy. Many small and big investors will now be able to contribute to the take-off of the wind industry in the country. Such decentralized investment will enable South Africa to overcome its current energy crisis. It will also help many South African communities to invest in wind farms and generate electricity, new jobs and new income. We are especially pleased as this decision comes shortly after the first North American feed-in law has been proposed by the Government of the Canadian Province of Ontario '' (Paul, 2009). However, the tariff was abandoned before it began in favour of a competitive bidding process launched on 3 August 2011. Under this bidding process, the South African government planned to procure 3,750 MW of renewable energy: 1,850 MW of onshore wind, 1,450 MW of solar PV, 200 MW of CSP, 75 MW of small hydro, 25 MW of landfill gas, 12.5 MW of biogas, 12.5 MW of biomass and 100 MW of small projects.

Zambia, the REFiT Strategy is intended to accelerate deployment of renewable power production projects through private participation for increased access to clean energy services in line with the National Energy Policy (NEP). Since Zambia's power generation is mainly large hydropower, during the 2015/2016 rain season, the Country experienced reduced power generation due to low water levels in the reservoirs because of reduced rainfall. To reduce over reliance on hydropower generation and diversify the generation mix the country considered power generation from renewable energy sources such as solar, wind, mini-hydro, biomass, geothermal. The Government through the Ministry of Energy developed the Feed-in-Tariff (REFiT) Strategy - a dedicated strategy (plan) with a clear institutional framework and an appropriate and effective financial regime to encourage private sector participation in power generation.

The REFiT Strategy was to be implemented in phases lasting three (3) years commencing in 2017. The Renewable Energy Feed-in-Tariff (REFiT) Strategy is being implemented through the Global Energy Transfer Feed-in-Tariff (GET FiT) programme with support of KfWDevelopment Bank of Germany and in April 2019, the Ministry of Energy announced the results of the first round of Solar PV Tender in which six (6) bidders were awarded to generate power solar at 120 MW. This was an international competitive tender which was launched in 2018. The tender represented the first phase of REFiT Strategy implementation. The second round involves the Small Hydropower Tender of up to 100 MW in which the Ministry is now receiving applications for Feasibility Study Rights from Developers who prequalified for the Renewable Energy Feed-in-Tariff (REFiT)/Global Energy Transfer Feed-In-Tariff (GETFiT) tender of 100 MW Small Hydropower Tender (Musalia, 2019). Despite the progress, investment in the electricity sector has still not grown to envisaged levels. Electrification rates remain low. The success of FIT policies has been attributed to the stability and certainty they offer for renewable energy investment (IEA 2008, Deutsche Bank,2009). While the GET FIT Zambia Solar PV tender achieved some of the lowest tariffs in the region and presented a good opportunity to diversify the country's energy mix, the implementation has stalled due to structural challenges in the sector (GETFIT, 2020). These policies create an environment that is conducive to leveraging capital toward RE deployment, which provides an effective framework for the wider adoption of RE technologies.

However, as with any energy policy, the benefits must be weighed against the challenges and costs. First, FIT policies can be complex and require significant analysis and consideration to develop a policy structure well-suited to meet the stated policy goals. Without careful consideration, it is possible to design an ineffective policy framework that fails to deliver on its objectives. Second, FIT policies require short-term payment level adjustments as well as long-term program design evaluations to best incorporate technology advancements, changing market conditions, and other relevant factors. This requires vigilance on the part of policymakers, and a willingness to revise the policy as market conditions change. Third, policy designers need to ensure that changes to the policy framework over time remain gradual and predictable, rather than abrupt and reactive. For example, Spain's solar PV market in 2008 saw unprecedented growth, partly due to aggressive FIT payments and also due to the rush to install projects before policy revisions occurred a year later (in September 2008). This led to approximately 2,600 MW of new solar PV capacity in 2008 and led to a drastic change to the policy framework, which included the imposition of annual caps on the total installed capacity of 500 MW for 2009 and 2010 (Spain 2008). This change has undermined investor and manufacturer confidence (Wang, 2009) and increased the risk perception of the Spanish solar market described by Deutsche Bank in 2009.

One of the lessons of the Spanish experience is that sudden and unpredictable changes due to frequent bureaucratic interventions are likely to undermine investor confidence and lead to a flight of capital – experience suggests that it is better to design FIT policies with a long-term perspective in mind and to ensure that policy adjustments occur incrementally rather than reactively (Deutsche Bank, 2009). Additionally, policymakers should consider the scale of deployment desired – the Spanish case demonstrates that aggressive tariffs combined with a good resource and inadequate oversight can create an explosive policy combination. Care should be given to the design of FIT policy caps (or other cost containment mechanisms), particularly for costlier resources. On the positive side, Spain's experience demonstrates that FIT policies can yield significant RE deployment quickly and effectively and can, therefore, be useful to meet aggressive RE targets. Since REFIT requires a well-designed FIT policy with a long-term perspective in mind and to ensure that policy adjustments occur incrementally rather than reactively (Deutsche Bank, 2009), this study will not consider REFIT strategy.

Load Control

Load control is where loads (e.g. heating, cooling, ventilation and lighting) can be switched on or off, often remotely, by the utility. In this case, the customers may have back-up generators or energy storage capability and generally have an interruptible agreement with the utility in return for a special rate. Utilities may even call on on-site generators to meet peak demand on the grid.

Energy-Saving Behaviours

Energy-saving behaviours is a demand response strategy for managing residential electricity demand in ensuring the electricity network's reliability, security of supply and maintaining a good balance between supply and demand for the electricity system of any country. Besides technology deployment, energy conservation can generally be achieved. Energy-Saving Behaviours can be categorized as investment and curtailment behaviours. Investment approach requires financial investment to improve energy–saving behaviours, while curtailment behaviours require minimum or no monetary investment towards energy saving. Further studies suggest that residential energy saving through behaviour change is faster than any other intervention. (Paramati *et al.* 2022). Consumers' energy-use behaviour change in their homes can be achieved relatively faster with no or minimum cost (Paramati *et al*. 2022). One study found that" …a changeover to more energy-efficient appliances will have a beneficial effect on the electrical energy consumption of domestic households, with annual average reductions in electrical consumption of 23% for households under investigation, such a measure may not necessarily be effective in reducing daily peak power demands of the individual households" (Borg and Kelly, 2011). In contrast, energy conservation through occupants' energy-use behaviour change can save electricity up to 21.7% during peak demand hours. (Asensio and Delmas, 2016). Thus, energy-saving behaviour could be an effective DSM option in any environment, in particular, developing countries, where DSM strategy deployment is either at the planning stage or at initial implementation stage. (Paramati *et al.* 2022). At the same time, energy-use behaviour change does not require any significant capital cost.

To change any energy-use behaviour, it is necessary that the consumer be motivated towards this practice, as the first step towards new energy-associated behaviour in residences. This motivation can be achieved through different sources, for instance, from society, related campaigns, education or even from economic factors. For example, a person might be motivated to reduce their electricity bill by reducing unwanted consumption at home (lights remaining on in an unoccupied room). This motivation inspires the person to set a goal in relation to electricity reduction that is 'aspiration'. In achieving the targeted goal, the person makes affordable changes in concrete terms, for example, replacing conventional bulbs with compact fluorescent lamps.

Next, the person tries to learn and practice possible energy-saving behaviours such as switching off of electric loads (e.g. lights, fans) in unoccupied rooms: practice. Later, at the end of the month the consumer measures their level of achievement by checking their electricity bill or by any other means, for example, indirect feedback: expected outcome. If the desired outcome is achieved, this practice and outcome cycle continues, otherwise the process starts from the beginning (i.e. motivation step). Although studies suggest that this type of new behaviour change does not always persist (Han *et al.* 2013) and (Kua and Wong, 2012) it might be an effective energy conservation step at the beginning of any DSM program. For example, this type of energy conservation might be effective before technology upgrades, such as energy-efficient appliance deployment, with immediate results in energy conservation, which is about 21.7% (maximum) (Asensio, O.I., Delmas, M.A.: The dynamics of behaviour change: evidence from energy conservation. J. Econ. Behav Organ 126, 196–212 (2016).

The Energy Efficiency and Conservation Master Plan (EECMP) of Bangladesh, a DSM program, shows that the inclusion of energy-saving behaviour, as a demand response strategy, in residences efficiency improvement in the use of home appliances could reduce electricity demand in the residential sector by about up to 50.7% with a minimum or no extra costs (Paramati *et al.* 2022). Despite the benefits of energy-saving behaviour as a demand response strategy, it has some limitations (Nahiduzzaman *et al.* 2018). Some of the limitation's energy-saving behaviour as a demand response strategy is that the achievements are temporary and there is need for continuous motivation (Han *et al.* 2013). Additionally, there might be direct and indirect 'rebound effects' due to this energy saving, that is, savings from energy services might be used for other similar services (Paramati *et al.* 2022). The concept of 'rebound effect' refers to a set of mechanisms that would be able to reduce the cost of the energy service; however, this reduction might increase the household energy consumption totally or partially negating the reduction achieved by the mechanisms (Freire-González, 2011). In direct rebound erect, the consumers might be motivated to consume more electricity at off-peak periods. On the other hand, in an indirect rebound effect, the consumers may purchase other goods and services which might have similar negative impacts. Nevertheless, 'indirect rebound is bounded by the consumer budget constraint' (Freire-González, 2011). For instance, a study in Beijing, China found that increase in energy efficiency of certain electrical home appliances such as air conditioners, cloth washers, and microwave ovens increases the indirect rebound effect significantly along with direct rebound (Yu *et al.* 2013).

In Zambia, Expressions of Interest for the Engagement of third-party partners for the rollout of the Smart House Initiative (SHI) at ZESCO Limited. In line with the same, ZESCO tendered for expressions of Interest for the Engagement of third-party partners for the rollout of the Smart House Initiative (SHI) at ZESCO Limited (ZESCO/EOI/101/2022). This tender follows ZESCO's conceptualization of the idea of a smart house that is expected to empower ZESCO customers with the ability to remotely control their household appliances using a smart ready gadget like a mobile phone, tablet, or laptop. According to ZESCO, there are instances when customers have missed the opportunity of saving energy and hence incurring unnecessary electricity bills by inadvertently leaving some household appliances like geysers, lights, fridges and stoves switched on when they step out of their homes. This initiative is expected to provide for customers to be adequately empowered to conveniently switch off supply from the palm of their hands thereby enhancing health and safety in households by preventing fire accidents that occur when household appliances like stoves, pressing irons and heaters are left on for prolonged periods. Therefore, ZESCO will provide a solution to allow ZESCO customers to remotely control their appliances whenever they are not in the vicinity of their homes. Additionally, ZESCO customers will have a clear and near real-time visibility of power consumption in their household appliances leading to speculation on the actual meter consumption. Equally ZESCO will have specific insight into how much the customers consume per household and will be able to plan for load management and maintenance in specific areas. Once this smart house solution is implemented, both ZESCO and the customers will have visibility into their power consumptions.

The smart house initiative will result into the following benefits to both ZESCO and its customers are

- ZESCO will be able to ascertain the power consumption usage per household and better understand the power consumption patterns which will lead to enhanced planning for maintenance and load management.
- Report on real-time power consumption and consumption growth trajectory per household giving ZESCO an understanding of statistics and trends on power usage at household level.
- The customer would have full knowledge and control to regulate the usage of their electrical appliances; and
- The application will enhance safety that will help avoid fire accidents which are normally caused by inadvertently leaving household appliances switched on. (Zambia Daily Mail-15th December 2022)

Although it may be true that residential energy-saving has these shortcomings, it is one worthwhile strategy to adopt at the beginning of any DSM plan as it requires a minimum amount of capital cost with immediate success (Paramati *et al.* 2022). Since this strategy involves technology deployment on the part of the system operator, and curtailment behavioural change towards energy-saving requiring little or no investment on the part of the electricity consumer, this will be the main focus of this study.

2.5. Use of Liquefied Petroleum Gas (LPG) as an Alternative Source of Heating

A majority of grid-connected households in Zambia use electrical power for nearly all of their domestic energy requirements. The use of electricity for cooking and heating has a high-power factor and tends to strain local power grids at peak periods. The recent grid-power shortages necessitate the application of the available electricity supply to sectors that will contribute the most to socio-economic growth, such as powering industries and commercial ventures, or household lighting and media power. However, alternative clean fuels such as LPG and liquid biofuels are yet to achieve widespread adoption as substitute energy carriers for domestic cooking and heating purposes. Liquefied petroleum gas (LPG) is a feasible alternative for clean household cooking and heating that could reduce the dependence on electricity for these tasks (Kimema *et al.* 2016). The transition to LPG, which holds a vast potential as an alternate clean cooking solution, can be catalysed and sustained by policies and programmes aimed at addressing affordability and accessibility (WLPGA, 2013). Conventional Liquefied Petroleum Gas (LPG) is a flammable mixture of hydrocarbons gases, most commonly propane, butane, and propylene. It is the cleanest form of fossil energy and is used as a fuel gas in heating appliances, cooking equipment, and vehicles. The need to switch to clean fuels like LPG for heating has never been more urgent. About one quarter of all the final energy used in the world is for space and water heating in buildings. Most heating needs are currently met by dirty fuels, such as heating oil, coal and traditional biomass, often in inefficient ways, or electricity produced largely from fossil fuels. The use of LPG would mitigate the threats towards worsening climatic changes and air quality. (Morgan, 2021).

The buildings sector (households and commercial and public offices) energy needs are currently met by a variety of fuels and forms of energy. Electricity is the leading fuel, used mainly for appliances, electrical equipment and, in some cases, space and water heating. The bulk of CO2 and other greenhouse gas emissions come from the production and use of fossil energy. According to the Inter-Governmental Panel on Climate Change (IPCC), global net emissions of greenhouse gases including CO2 would need to fall by 45% between 2010 and 2030 and to zero by around 2050 to be on track to meet the long-term goal of limiting the temperature increase to 1.5 degrees under the 2015 Paris Agreement (IPCC, 2018). The decarbonisation of energy use in buildings will be vital to achieving climate goals. Buildings contribute around 30% of global energy-related CO2 emissions – 8% directly from the burning of fossil fuels indoors and the remaining 22% indirectly from producing the electricity used in buildings using fossil fuels. Reducing buildings-related emissions will, therefore, need to involve a shift to less carbon-intensive fuels alongside the decarburization of power generation.

As a heating fuel, LPG can be far less carbon-intensive than electricity, even when the latter is used to power a heat pump. LPG in the case of electrical resistance-heaters and about twice as high in the case of conventional electrical heat pumps. On average worldwide, the carbon intensity of LPG is approximately 70% lower than that of electricity. (Morgan, 2021).

The types of incentives that encourage LPG for heating vary. For example, Chile has adopted policies that actively encourage LPG use for social, economic and environmental reasons. The main incentives include building codes, a sustainable heating programme and information campaigns to encourage switching from firewood to LPG and other clean fuels. France axes LPG less than heating oil and electricity and offers incentives for efficient boilers. The federal governments of the United States and Germany have adopted a more technology-neutral approach that allows given fuels and technologies to compete freely within a regulatory framework aimed at lowering energy use and energy-related environmental effects, though specific incentives for installing efficient LPG heating systems do exist. In Germany, a tax rebate is available for LPG used for co-generation while the introduction of carbon pricing for heating fuels and the extension of a ban on the installation of heating oil systems from new to all buildings will increase opportunities for LPG, and in the United States, federal and state tax credits for efficient LPG boilers and an investment credit for co-generation are available. LPG is also encouraged through federal boiler standards and labelling schemes, research and development programmes and procurement rules. The United Kingdom encourages LPG for heating mainly through the absence of an excise tax that is applied to heating oil (Morgan, 2021).

In Zambia, a lot of efforts are being made by Government to promote the use of LPG. The pricing of LPG in Zambia is threefold; the wholesale price set by the Energy Regulation Board (ERB) using the Cost-plus Model and the export price set by TAZAMA. The retail price for imported LPG is determined by the trader or importer of the product. Under the Distribution License, OMCs are allowed to engage in the distribution of LPG amongst other petroleum products, without a specific requirement for dedicated LPG storage (Sikwanda, 2019). Besides that, ERB regulates the production, storage, distribution, transportation and retail of LPG under the existing licensing regime for petroleum products.

According to the study that was conducted by ERB, it was established that 9.7 percent of households in Lusaka district had used LPG as an energy source for cooking before, among these 3.5 percent of the households indicated that they were currently using LPG, while 6.2 percent stated that they had stopped using LPG. The use of LPG as the main source of energy for cooking accounted for 2.5 percent among high-cost areas, 2 percent among the medium cost areas and none among low cost areas (Sikwanda, 2019). Additionally, 46.7 percent of the households perceived LPG to be cheaper compared to alternative forms of energy as a factor in starting to use LPG. This was followed by 46.4 percent who indicated that it was due to load shedding. On the other hand, 4.1 percent indicated that LPG was readily available as a motivating factor of using it, while 2.8 percent stated that food tastes better if cooked using LPG. The reduction in ZESCO load shedding hours was cited as a contributing factor to stopping the use of LPG by 28.8 percent of the households followed by the perception that it was expensive at 14.1 percent. Meanwhile other assertions such as causing health problems at 12.1 percent; 9.6 percent indicated that it was dangerous; 9.3 percent gave away the gas cylinders and 7.1 percent indicated that the equipment got stolen. Other factors accounted for 14.1 percent. Overall, 81.2 percent of the households stated that they had heard of LPG, while 18.8 percent stated that they had not. Further the results indicate that the highest percentage (93.8%) of the households heard of LPG from family and friends, 2.5 percent on the internet, 2.4 percent on TV and 1.3 percent in newspapers. Despite this level of awareness, most households (88.3%) were of the view that there was no adequate awareness on the uses of LPG as a form of energy.

2.6. Load Shedding/ Rolling Blackouts

Load Shedding or Rolling Blackouts is generally considered to be the deliberate shutdown of electric power in a part or parts of a power-distribution system, generally to prevent the failure of the entire system when the demand strains the capacity of the system. According to the UNIDO module on Sustainable Energy Regulation and Policymaking for Africa, Rolling Blackouts are the systematic switching off of supply to areas within a supplied region such that each area takes turns to “lose” supply. The energy distribution industry may use rolling blackouts to reduce demand when the demand surpasses the capacity. Utilities or municipalities in these cases would try to publish or announce a schedule so that businesses and homes can plan their use of energy for that period. Rolling blackouts generally result from two causes: insufficient generation capacity or inadequate transmission infrastructure to deliver power to where it is needed.

Rolling blackouts are also used as an emergence response strategy to cope with reduced output beyond reserve capacity from power stations taken offline unexpectedly, such as an extreme weather event. In well managed under-capacity systems, blackouts are scheduled in advance and advertised to allow people to work around them, but in most cases, they happen without warning, typically whenever the transmission frequency falls below the 'safe' limit. A rolling power outage allows the available energy supply to be shared among customers. It also protects sensitive sites like hospitals, from power loss. If the grid was not protected against these potential overloads, the damage could cause a complete shutdown of the grid. Then everyone could be left without power. Recently, in Western Cape of South Africa, consumers were subject to a fairly long period of rolling blackouts. This was due to demand surpassing capacity at one unit of Koeberg Power Station under unplanned maintenance. These cuts were not always well communicated to the customers or did not run according to the published schedule causing much confusion, lost production and even lost goods such as refrigerated products. However, the winter demand was largely met due to customer participation in energy efficiency and DSM initiatives.

Load Shedding was one of the load management measures that ZESCO undertakes, particularly in 2015, when Zambia experienced a drastic reduction in electricity supply which was attributed to the reduced generation by ZESCO Limited (ZESCO) due to the low water levels in the reserves caused by poor rainfall in the 2014/15 rainy season. The power deficit in 2015 ranged from 560 to 1000 MW. By July 2015, ZESCO had increased the extent of load shedding to at least eight (8) hours a day for the majority of its household, commercial and industrial consumers. The load shedding affected the most business operations and financial viability. From literature, it has been investigated that small enterprises are the most likely to be adversely affected by measures such as load shedding (Kazungu*et al.* 2014). This is because, small enterprises are less resilient and most of them are not insured or have limited capacity to invest in alternative energy sources.

However, the small enterprises importance in the economy, it is critical that the impact of load shedding be mitigated (Mwila *et al.* 2017). This study has included load shedding in the development of the energy saving mode, as its increase in frequency and duration has been cited in the ERB report as the factor that contributed to the update, and its decrease as a reason for discarding the use of LPG as a source of heating for homes (Sikwanda, 2019).The small enterprises are the most adversely affected by measures such as load shedding, as they are less resilient (Kazungu *et al*. 2014). Load shedding has been considered as it is easy to be implemented by the system operator and is a very effective strategy for managing excess load on the part of the supply authority, but adversely affect the electricity consumers.

2.7. Information Dissemination for Energy Saving and Efficiency

Energy saving and energy efficiency improvement in organisations requires raising awareness by campaigns informing staff of energy-consuming organisations about energy efficiency options and demand side management techniques (Lugano, 2006). These campaigns may be marketed by personal contact and visual media (such as posters, fliers, leaflets, brochures and video clips), as well as carrying out energy audits. (UNIDO “Sustainable Energy Regulations and Policymaking for Africa”). Energy Saving and Efficiency Information Dissemination is an information-related policy which is based on available related information on demand side management schemes. This type of policy is implemented by the end users, who in this case in the residential consumers. One of the challenging tasks in achieving Energy Saving and Efficiency Information Dissemination as a DSM strategy is the consumers’ response to adopt this type of strategy, and their active participation in achieving a successful DSM programme (Paramati *et al.* 2022). There is generally a low awareness of energy efficiency and DSM programmes in developing countries. Since energy savings and energy efficiency improvement depend on the combined effort of many individuals, a plan to market and implement the programme needs to be prepared (UNIDO “Sustainable Energy Regulations and Policymaking for Africa”).

2.8. Smart Grid

Just to apply most of the DSM programmes or strategies, the electricity network needs to be on the smart grid (Paramati *et al.* 2022). SMART technology means “Self-Monitoring Analysis and Reporting Technology”. This technology is used to provide cognitive awareness to objects, by making use of advanced technologies like internet of things, artificial intelligence, machine leaning and big data. One of the applications of smart technology is the smart grid. The European Union Commission Task Force for Smart Grids defines Smart Grids as: "An electricity network that can cost efficiently integrate the behaviours and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.

A Smart Grid is characterized with ten attributes for maintaining a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following: (1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid. (2) Dynamic optimization of grid operations and resources, with full cyber-security. (3) Deployment and integration of distributed resources and generation, including renewable resources. (4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources. (5) Deployment of 'smart' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation. (6) Integration of 'smart' appliances and consumer devices. (7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal storage air conditioning. (8) Provision to consumers of timely information and control options. (9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid. (10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services (EISA, 2007). This study has not considered smart grid in the development of the model owing to its many challenges relating to requirement for smart appliances to be implemented, management of data and information generated, and control options, reliability of the system, cyber-security, standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

A smart grid needs smart appliances, because much of the investment in ‘smart grids’ could be stranded unless appliances can respond to utility load control signals or sense the condition of the grid. The smart appliances are electronic devices in the household environment, which are applicable to smart grid services like so-called demand response activities, remote monitoring, scheduling, energy consumption adaptation programs, etc. The application of smart appliances in demand response services, has provided the utility company, grid operator or aggregator to achieve grid stability through peak levelling or renewable energy integration, and provide for a consumers' active market participation and energy shift trading (George, 2011). There are three types of smart appliances. The respective type is according to the principal operation.

The first type is a Fully Automatic Smart Appliance. This type is where a consumer has no influence on the operation. It is suitable for refrigerators and freezers. A Set and Forget type is where the consumer defines the (daily) operation interval when the process needs to be finished, but leave the smart appliance control to do the job. It is suitable for the washing devices. The third type, Case by Case Decision, is one where at every operation cycle the consumer is asked how to proceed. For instance, by means of a dedicated “smart” button the appliance instructs whether to use an ordinary process or the operation is controlled by some demand response procedure (George, 2011). This type is appropriate for behaviour appliances (electrical hobs, hoods, ovens), a situation where the user may need to decide on some external parameter, i.e. electricity market price before he starts operation.

There is a widespread expectation in the United States and around the world today that the smart grid is the next big thing, a disruptive technology poised to transform the electric power sector. The belief is that the use of smart meters and other devices and systems will allow consumers to manage their own electricity use to radically reduce energy costs. The implementation of a smart grid system will enable the widespread use of renewable energy sources, allow more-distributed electricity generation, and help reduce carbon emissions (Makovich, 2011). The smart grid technologies are non-disruptive and are slowly and peacefully getting adopted. The downstream smart grid will ultimately be highly disruptive to the traditional utility business model. Physically, the smart grid will be the platform for integrating vastly more consumer-and community- sited generation and storage, sending power in multiple directions. It will enable utilities and other retailers to adopt much different pricing than today’s monthly commodity tariffs. Pilot programs across the United States, Canada, Europe, and Australia continue to show that consumers do respond to dynamic pricing rates that are well designed and clearly communicated (Peter *et al.* 2011). The Olympic Peninsula, dynamic pricing has been shown to be very successful.

Although dynamic or real-time power pricing schemes, are usually higher than traditional rates during peak periods and lower during off-peak periods, most consumers use more electricity during peak periods than during off-peak periods. Thus, unless they can shift enough of their power use, typical consumers face a higher bill with a move to real-time pricing. Most consumers, according to research, doubt they can do this and expect that real-time pricing will increase their bills. Economists have long considered the ability to use real-time prices that reflect the marginal cost of electricity at different times of the day as a more economically efficient way to price electricity. The Public Utility Regulatory Policy Act of 1978 encouraged utilities to use time-of-use–based rates to price electricity. Congress, in the Energy Policy Act of 2005, encouraged state regulators and utilities to shift from fixed rates to time-varied electric rates in order to increase energy efficiency and demand response. However, most consumers focus on their pocketbook rather than the theoretical basis of this supposedly more efficient pricing system. After all, the prospect of real-time pricing involves higher and more unpredictable prices; on an hour-to-hour basis, the marginal cost of electricity is hard to predict and can change by a factor of 100 during any given day. Research clearly indicates that most consumers far prefer the stable and predictable power pricing schemes they currently have.

Participation in almost all dynamic pricing programs in the United States has been voluntary. Currently, time-of-use rates are offered by more than half of investor-owned utilities. Many of these programs have been offered for years, and in some cases decades.

Many smart grid initiatives are going forward without any dynamic pricing schemes and those that do use dynamic prices employ highly muted price signals. Currently, there are no real-time pricing mandates for small customers anywhere in the United States. In addition, these consumer preferences often translate into laws and regulations. California passed a law prohibiting dynamic pricing for residential customers, and New York imposed restrictions on the use of such pricing. In Maryland, the public service commission refused Pepco's request to implement one form of dynamic pricing, even on an opt-in basis, because it considered the risk too great that customers would opt into the system with the expectation of lower bills only to find that, at least initially, the new rate would result in higher bills. The direct benefits of smart grid investments have not yet proven certain or significant enough to fully offset the costs of implementation. The implication is clear: The United States is not moving to a rapid full-scale deployment of smart grid technologies and systems anytime soon. Therefore, investment in smart grid technologies in the years ahead will depend to some degree on the political tolerance for increases in power prices, because developing a smarter grid is not likely to reduce bills, because the percentage increase in prices will probably not be offset by a larger reduction in electricity use enabled by the smart grid. Besides that, the smart grid implementation is occurring during a period of rising real power prices, and even if smart grid savings could offset costs, there are also other factors that are continuing to push prices up.

There are also opposition and concerns that have centred on smart meters and the items such as remote control, and remote disconnect, enabled by them. While modernization of electrical grids into smart grids allows for optimization of everyday processes, a smart grid, being online, can be vulnerable to cyber-attacks. Cyber Security in Smart Grid has a critical operation because numerous devices individually commercial and domestic will be connected via a series of networks to communicate and delivering the security to the networks with various techniques (Janicke *et al.* 2018). The potential vulnerabilities of Smart Grid technology and its information networking are associated with information security. Due to the heterogeneous communication architecture of smart grids, it is quite a challenge to design sophisticated and robust security mechanisms that can be easily deployed to protect communications among different layers of the smart grid-infrastructure (El *et al.* 2018). Hackers have the potential to disrupt these automated control systems, severing the channels which allow generated electricity to be utilized, and they can also launch integrity attacks which corrupt information being transmitted along the system as well as de-synchronization attacks which affect when such information is delivered to the appropriate location (Paul *et al*. 2005). According to the US Energy Department, cybercriminals have infiltrated the U.S. electric grid before on numerous occasions, and in 2022, the number of direct physical attacks on U.S. power grids soared 77 percent to 163.

This study has not considered smart grid in the development of the model owing to its many challenges relating to requirement for smart appliances to be implemented, management of data and information generated, and control options, reliability of the system, cyber-security, standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

3. Methodology

3.1. Study Design

The research design in this study is a mixed research method employing both qualitative and quantitative methods. An attempt was made to obtain respondents' opinions on enhancing energy-saving behaviours of domestic electricity as a demand-side management model for minimising load shedding in Zambia.

Though this research is qualitative, a quantitative method was used to analyse the data collected from electrical engineering professionals. The purpose of using the qualitative method was to get data from direct sources and understand the perception of the electrical engineering professionals in terms of policy, impact, and factors affecting energy-saving behaviours of domestic electricity consumers (Gazzola *et al*. 2020). Implementing the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets.

The quantitative method was introduced to understand the interpretation of data and get the expected ideas from the respondents. The research aims to understand the various energy demand-side management and develop a model to enhance domestic electricity consumers' energy-saving behaviours in Zambia. Primary data were collected using a survey questionnaire, and secondary data was collected through literature review from various sources such as articles, papers, reports, magazines, websites, etc (Kandel, 2020). The SPSS software will be used to analyse the data, and description statistics and chi-square will be used in relation to cross-tabulation. The description statistics will be used to show exactly how the data was distributed, and for this, standard deviation, kurtosis, scenes, and mean were considered most to analyse the data.

3.2. Population

The target population for this study consists of all the electrical practising engineering professionals in Zambia. However, only the 2024 electrical practising engineering professionals registered with the Engineering Institution of Zambia from the four membership categories were randomly stratified and sampled for ease of administration, retrieval, collection and data analysis.

The selected four membership categories are as follows

- Registered Engineers
- Registered Technologists
- Registered Technicians
- Craft Persons

The sampling frame was prepared as a physical registered list of the 2023 electrical practising engineering professionals registered with the Engineering Institution of Zambia. The population was divided into registered engineers, registered technologists, registered technicians, and craft persons.

3.3. Sampling Frame for Questionnaire Survey

The sampling frame was prepared as a physical registered list of electrical practising engineering professionals registered with the Engineering Institution of Zambia. The population is divided into registered Engineers, registered technologists, registered technicians, and Craft persons of the electrical category. A sample frame is used in the research paper to specify the population interested in the research paper. This sampling framework comprises the researcher's components to finalise a population group for the sample size. The limitation in accessing the resources and the accessibility can hinder the researcher from collecting the population for the study's conduction.

3.4. Sample Size

The sample size was selected as the parameter for stratification to ensure the sampling elements were homogenous. They were divided into four groups or strata based on their membership in the Engineering Institution of Zambia. Proportionate stratified sampling was found suitable.

A standard normal deviation for 95 per cent confidence with a 5 per cent marginal error was accepted for this study. The sample was determined using the following bio-statistical formula to estimate the sample in a survey.

$$N = \frac{Z^2 P(100\% - P)}{E} \qquad \text{Equation (1)}$$

Source: Sample size calculation: Rao (2007)

Where N is the sample size required, P is the estimated proportion of the sample, E is a marginal error, and Z is the standard normal deviation with a factor “1.9,” relating to 95 per cent confidence. From the 3583 electrical practising engineering professionals registered with the Engineering Institution of Zambia in 2024, the sample was estimated to be 384

A proportionate fraction was calculated from the total sample of 384 by dividing the total population by the sample size.

The population is divided into 990 Registered Engineers, 530 Registered Technologists, 515 Registered Technicians and 1548 Craft persons of the electrical category, totalling 3583. The population register was randomly stratified and sampled to get 106 Registered Engineers, 57 Registered technologists, 55 Registered technicians and 166 Craft persons.

The total was added to form a 384-population sample of the 2024 electrical practising engineering professionals registered with the Engineering Institution of Zambia. The strum sample was then computed as presented in Table 3-1

Table 1 Sample frame for different strata of surveyed respondents

Stratum	***Population***	***Sample Size***
Registered Engineer	990	106
Registered Technologist	530	57
Registered Technician	515	55
Craft persons	166	166
Total	1548	384

3.5. Geographical area of study

The study was conducted by the 2024 practising engineering professionals and engineering organisation organisations/units registered with the Engineering Institution of Zambia. The Engineering Institution of Zambia has registered electrical practising engineering professionals' membership of 1548 according to the 2024 register, representing 17.66% of the total 2024 practising engineering professional membership population in Zambia. Moreover, the geographical area of the research paper denotes a distinctive boundary, including city, boundary and continent for the research paper.

3.6. Research Instruments

The research instrument used in this study was a two-part self-administered survey questionnaire. The second part was designed for the study and consisted of three sections, each rated on a five-point Likert-type scale ranging from 1 to 5.

- Strongly disagree represented by 1
- Strongly agree, represented by 5.

The first section of the questionnaire is designed to measure the respondents' (2024 registered electrical practising engineering professionals) understanding of the factors affecting energy-saving behaviours and implementation of technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets by domestic electricity consumers. This particular section had a total of 8 questions listed from 1 to 8.

The second section is designed to assess the effectiveness of the National Energy Policy of 2019 in promoting and addressing the challenge of energy-saving behaviour. It is also designed to assess the implementation of recommended technology for alternative energy sources for heating, lighting, and powering electronic gadgets to end load shedding. The section comprises 15 questions listed from (1 to 15).

The third section of the questionnaire is designed to assess the 2024 registered electrical practising engineering professionals' perception of the quantum contribution of implementing recommended technology for alternative energy sources other than grid electricity to the national power demand. The final part is used to collect the respondents' demographic data.

The research proceeded with a cover letter introducing the researcher, explaining the purpose of the research, and soliciting assistance in providing the required information.

3.7. Data Collection Method

The study used a stratified random sampling design. This design provides the best representation of the entire population being studied. It provides an equal opportunity for all respondents in the target population to be included in the study. It also enables inferences to be generalised to the target population. The respondents have been clustered into four categories representing four membership levels of the 2024 registered electrical practising engineering professionals to arrive at the final sample. A total number of three hundred ninety (390) questionnaires were then distributed, and only Three hundred five (305) questionnaires were returned, representing a response rate of seventy-eight (78.2%) per cent.

3.8. Pilot Study

The self-administered questionnaire was pilot tested on an engineer, technologist and craft person. The purpose is to determine whether the questions and instructions were unambiguous and if the respondent found the question appropriate. The unambiguous questions were removed or reconstructed. The pilot study will help the researcher assess the questionnaire's validity. According to Basavaathappa (2009), research instruments should be pilot tested to detect weaknesses or errors in the instrument from the targeted population.

3.9. Validity of Information

The research relies on the information that is collected in the field. The respondents will give the researcher answers they would be comfortable with so that the information collected is valid up to the level of truth the respondent gave. The questionnaire will embody the closed approaches to allow respondents to make scores. This is enough to follow the conceptual or theoretical framework the researcher used in the study.

4. Results and Conclusion

4.1. Demographic Data

This part of the chapter provides basic sociodemographic variables and their distribution by category. Socio-demographic variables included the respondents' categories, gender, sex, age, academic qualification, and experience in teaching. Demographic factors can influence the consumption and investment rate of resources, measuring the growth rate of structural productivity, living standards, saving rates, and economic growth rate. These factors provide different information gathered from various types of participants related to the topic of the research paper. The primary methods of the demographic data analysis help to discuss the methods and conduct the comparative study related to age, sex, and caste.

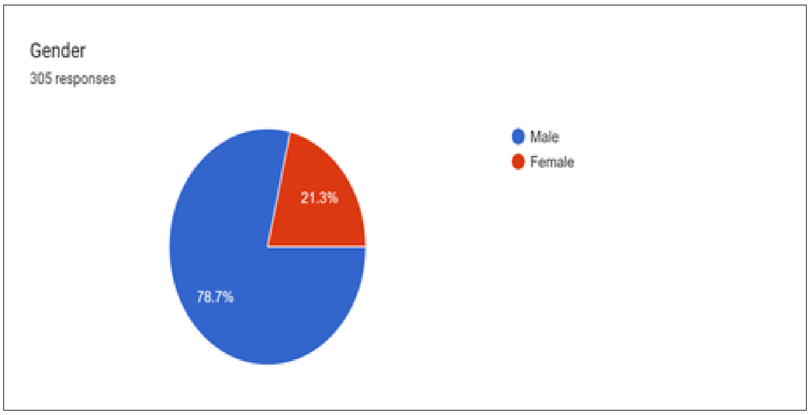

Figure 1 Gender and Age distribution of the respondent

4.1.1. Gender

The demographic characteristic of the respondents from the 2024 electrical practising engineering professionals registered with the Engineering Institution of Zambia from the four membership categories shows that, out of three hundred and ninety (390) distributed questionnaires, a total of three hundred and five (305) questionnaires were returned and valid. Thus, the research involved 65(21.3%) female and 240 (78.7%) male respondents, as shown in the pi-chart below. Additionally, the doughnut reviews the age groups of the respondents. The doughnut below indicates the age distribution of the 305 respondents sampled for the research. As shown below, the age groups less than 39 and above 50 had the highest percentage, with 75% combined with 46% coming from the age group less than 30, which suggests that the average age of the respondents is less than 30.

4.1.2. Work Experience

The respondents' work experience was another significant variable for this study. The energy-saving behaviours of domestic electricity consumers in Zambia establish the best mechanism for enhancing the study sought to establish their work experiences.

The demographic characteristics of the respondents from the three targeted areas in Zambia show that out of three hundred and ninety (390) distributed questionnaires, three hundred and five (305) questionnaires were returned and valid. Thus, the research involved 65(21.3%) female and 240 (78.7%) male respondents, as shown in the pi-chart below. Additionally, the doughnut reviews the age groups of the respondents. The doughnut below indicates the age distribution of the 305 respondents sampled for the research. As shown below, the age groups less than 39 and above 50 had the highest percentage with 75% combined with 46% coming from the less than 30 age group, which suggests that the average age of the respondents is less than 30

4.2. Factors Affecting the Energy-Saving Behaviours of Domestic Electricity Consumers

This section deals with the electricity practitioners' understanding of the factors affecting the energy-saving behaviours of domestic electricity consumers. Figure 4.2 below shows the distribution of consumer's ability to operate the technology for alternative energy sources.

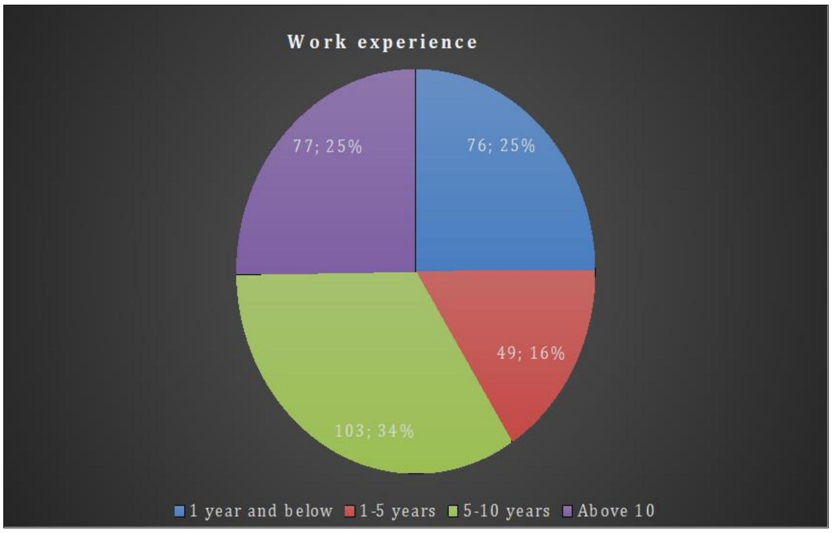

Figure 2 Average consumer can operate the technology for an alternative source of energy

Respondents were asked if an average domestic electricity consumer can operate the technology as an alternative energy source for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity. Responses indicate that 44% agreed and 23% strongly agreed, indicating that 63% of the average domestic electricity consumer can use technology as an alternative energy source. It was the researcher's interest to establish the respondent's views on the ability of the consumer to operate the technology.

Respondents were asked if the cost of buying, installing, operating and maintaining technology for alternative energy for heating, energy-efficient lighting and powering of electronic gadgets, or other models for serving electricity is beyond the ability of an average domestic electricity consumer, and 35% agreed. In comparison, 14 % strongly agreed that the cost exceeds an average domestic electricity consumer. However, 14 % strongly disagreed, 27% disagreed with the above statement, and 10% neutral. 49% of respondents agreed that the cost is beyond an average domestic user. It was further sought to establish the availability of safety information about using technology for alternative energy.

Responds were further asked if safety information about using technology for alternative energy for heating, energy-efficient lighting and powering electronic gadgets, or other models for serving electricity. 31% disagreed, and 27% strongly disagreed. The other factor considered was whether load shedding can influence domestic electricity consumers to invest in alternative energy technology.

The researcher tried to establish if load shedding can influence a domestic electricity consumer to invest in technology for alternative energy for heating, energy-efficient lighting, and powering of electronic gadgets, or other models for serving electricity, 32% of the respondents strongly agreed. In comparison, 41 % agreed, bringing the total percentage to 73% of the respondents who agreed, even though the degree of agreeableness differed to a certain degree. It was also the researcher's interest to establish whether Incentives and penalties can persuade domestic electricity consumers to use recommended alternative energy.

Does the application of incentives and penalties persuade domestic electricity consumers to use recommended technology for alternative energy for heating, energy-efficient lighting and powering electronic gadgets, or other models for serving electricity? 41 % of the respondents agreed, while 24% held an opposite belief. Having established that most of the respondents agreed with the statement that Incentives and penalties can persuade domestic electricity consumers to use recommended alternative energy, the researcher further sought to establish whether consumers are not motivated to use recommended alternative energy.

Respondents were asked if domestic electricity consumers need to be sufficiently motivated to implement the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity. 74% of them agreed, and 41 % strongly agreed with the assertion. Subsequently, the study sought to establish whether consumers knew the benefits of implementing technology for alternative energy.

Participants were asked if domestic electricity consumers knew the benefits of implementing technology for alternative energy for heating, energy-efficient lighting and powering electronic gadgets, or other models for serving electricity. 52% don't believe they know the benefits of alternative energy sources, while 32% are neutral. Having established the results as indicated, the study further sought to establish whether consumers can't use alternative energy. Domestic electricity consumers were asked if they are so used to electricity that no matter what is done, they cannot change to using recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity. 31% disagreed, while 27% strongly disagreed, bringing the total percentage to 58% of those who do not think consumers cannot adopt alternative energy. 21% agreed, and 21% were neutral.

4.3. Effectiveness of The National Energy Policy of 2019

This section assesses how effective the National Energy Policy of 2019 has been in promoting and addressing the challenge of energy-saving behaviour and implementing recommended technology for alternative energy for heating, energy-efficient lighting and powering of electronic gadgets, or other models for serving electricity in Zambia. Several factors were considered in this study, and also the follow up to establish the effectiveness of the 2019 National Energy Policy.

4.3.1. Political will

Political will is significant in the effectiveness of the National Energy Policy 2019. The political will power helps to establish its significance and effect with the sought to establish whether there was political will to influence the recommended technology.

When respondents were asked if there is a political will to influence the use of recommended technology for alternative energy for heating, energy-efficient lighting and powering of electronic gadgets, or other models for serving electricity, 67% agreed (27 strongly agreed while 40 agreed). The other factor considered to establish the effectiveness of the national energy policy was the policy framework

4.4. Policy Framework

The policy framework is of prime importance in realising the effective usage of power in Zambia. The study sought to establish the effectiveness of the energy policy of 2019 with consideration of the use of technology, implementation of the Renewable Energy Feed-In-Tariff policy, motivation for domestic electricity consumers to invest in recommended alternative energy, if interest loans motivate domestic electricity consumers to invest in alternative energy, if it also promotes and encourages the use of recommended technology for alternative energy, if it provides incentives to encourage the participation of local investors in recommended technology for alternative energy and if it provides for demand response as demand side management strategy.

When asked if the National Energy Policy of 2019 provides for the use of technology to enhance energy-saving behaviour among domestic electricity consumers, 66% (39% disagreed while 27% strongly disagreed) of the respondents said it does not provide for the use of technology to enhance energy-saving behaviour.

In comparison, 36% strongly agreed (72%) that the Renewable Energy Feed-In-Tariff policy needs to be effectively implemented in Zambia to accelerate investment in renewable energy technogy.As shown in figure 4.11 above, 55% of the respondents agreed that the policy framework does not provide incentives to motivate domestic electricity consumers to invest in recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity.

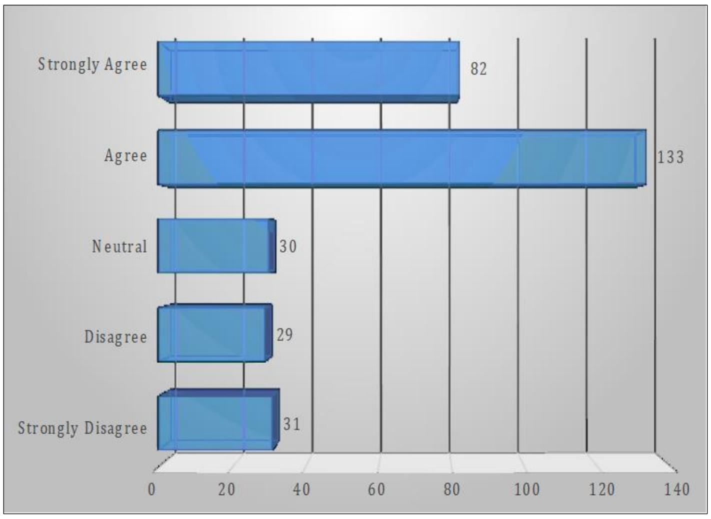

Figure 3 Policy does not make bank's interest rate on loans to motivate domestic electricity consumers to invest in alternative energy

The data presented above indicated that 215 out of 305 believe that the policy does not provide for bank interest rates on loans to motivate domestic electricity consumers to invest in recommended technology for alternative energy for heating, energy-efficient lighting and powering of electronic gadgets, or other models for serving electricity.

Furthermore, the participants responded about the nature of the policy framework on industry electricity consumers than domestic consumers as follows:

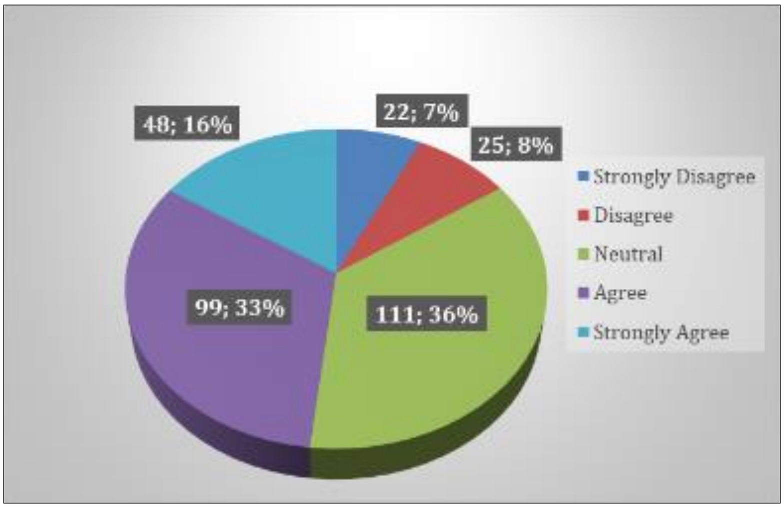

Figure 4 The policy framework promotes energy-efficient technologies more by targeting industry electric consumers than domestic consumers

Here, 33% agreed, and 16 % strongly agreed with the assertion that the National Energy Policy 2019 framework focuses more on industry electricity consumers than domestic consumers in promoting energy-efficient technologies. However, 36% were neutral, and 15% disagreed.

When asked whether Zesco's policy framework promotes and encourages the use of recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets to save electricity for exporting, 215 out of 305 respondents thought that it does not, 64 thought that it does, and 26 were neutral.

The data presented in the figure above show that 124 out of 305 do not believe that the ERB policy provides incentives to encourage local investors' participation in recommended technology for alternative energy. Sixty do agree, while 121 are neutral.

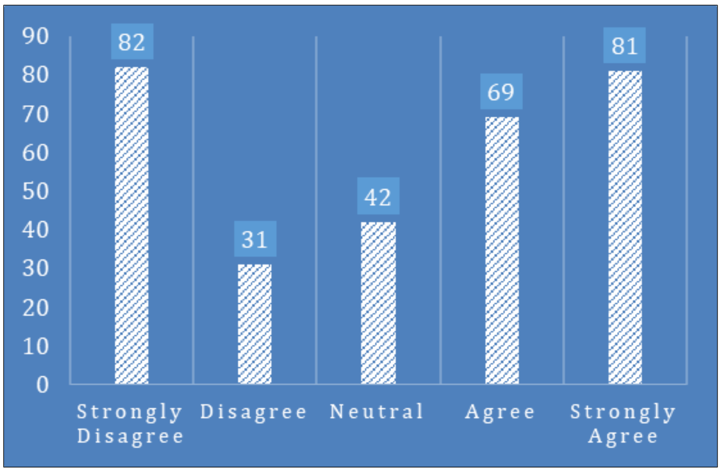

Figure 5 The policy framework on electricity tariff does not provide for demand response as a demand-side management strategy

When asked to comment on whether the policy framework on electricity tariff does or does not provide for demand response as a demand-side management strategy, 150 (49%) out of 305 agreed (81 having a higher degree of agreeableness), 113 (37%) disagreed, and 42 (14%) were neutral.

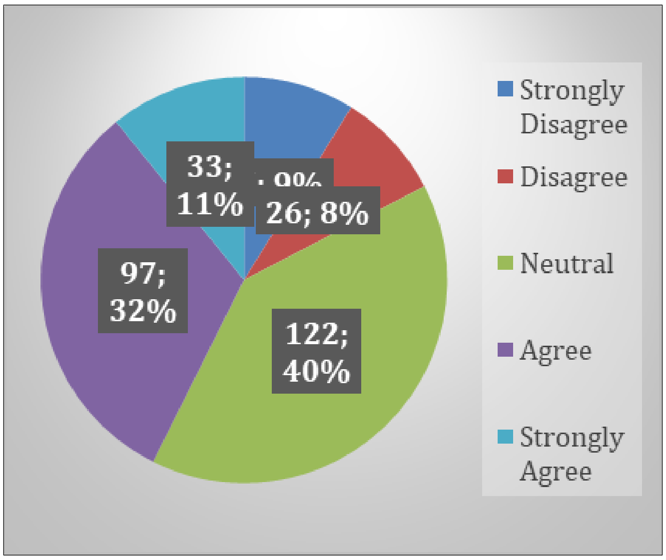

Figure 6 ERB policy framework on load shedding

From the data presented in the figure above, 43% believe that the ERB policy framework allows Zesco to use load shedding to protect the installation during excess demand, but also as a means to persuade domestic electricity consumers to use recommended technology for alternative energy for heating, energy-efficient lighting and powering of electronic gadgets, or other models for serving electricity.

4.5. Implementing Recommended Technology for Alternative Energy

The section deals with the quantum contribution of implementing recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity to meet the national power demand and its social and economic impact. The findings are tabulated in the figures below. Alternative energies are the most important factors in implementing new technological aspects to reduce excessive energy consumption and improve the condition of electricity. This alternative energy technology is more convenient as it is environment-friendly and reduces the technological dominance in current practices.

Respondents were asked if, if all domestic electricity consumers invested in and implemented the recommended technology for alternative energy, a great contribution towards reducing load shedding in the country could be made, and 82 % agreed (45 % strongly agreed and 37 % agreed).

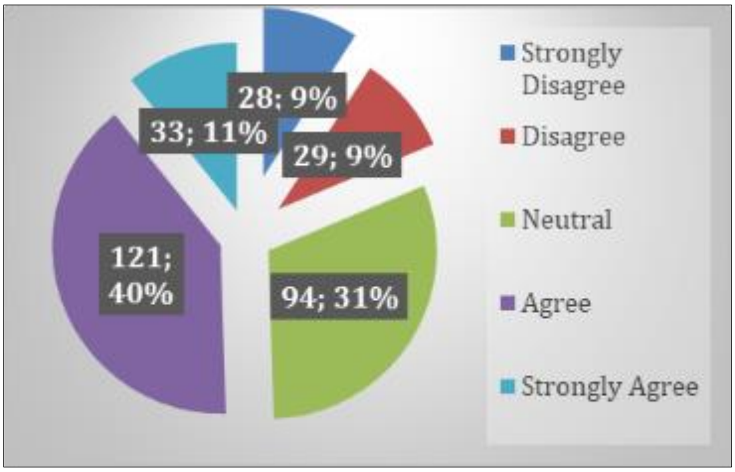

Figure 7 The primary beneficiary of implementing recommended technology for alternative energy

The respondents were asked if the domestic electricity consumers were the primary beneficiaries of implementing recommended technology for alternative energy. From the data presented in the figure above, most participants (51%) believed that the primary beneficiaries of implementing recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets are not domestic electricity consumers.

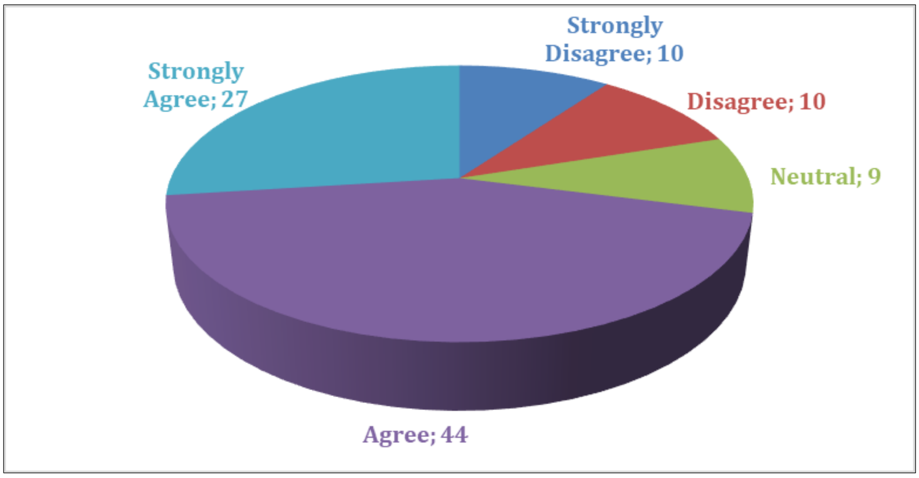

Figure 8 Implementing the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets will have little effect on the nation's social and economic development

Again, the majority (203 out of 305) do not agree with the assertion that implementing the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity would have little effect on the nation's social and economic development.

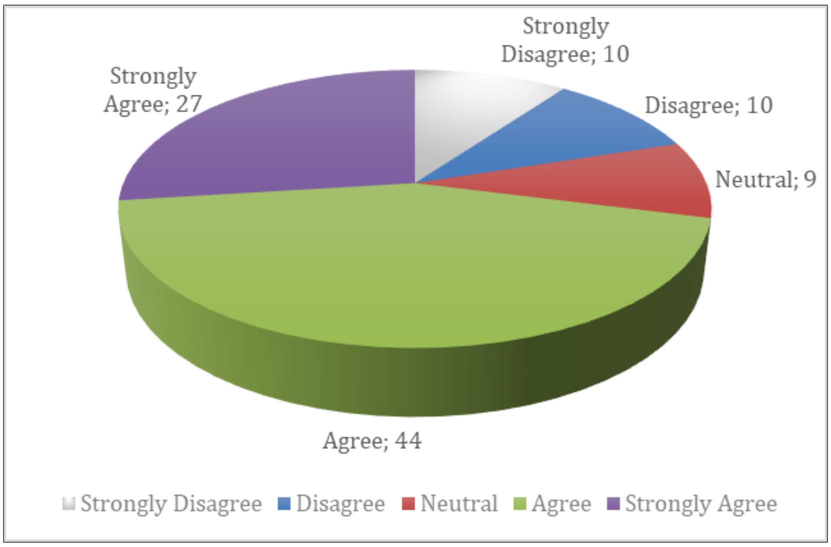

Figure 9 Investment in the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets can sensibly contribute to job creation

When asked if investment in the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity can sensibly contribute to job creation, 44% agreed, 27% strongly agreed, bringing the total agreeableness to 71%.

Most of the respondents (71 %, 31 % strongly agreed, 40% agreed) believe that investment in the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity will positively contribute to the operations of small and medium enterprises (SMEs) like saloons and welders.

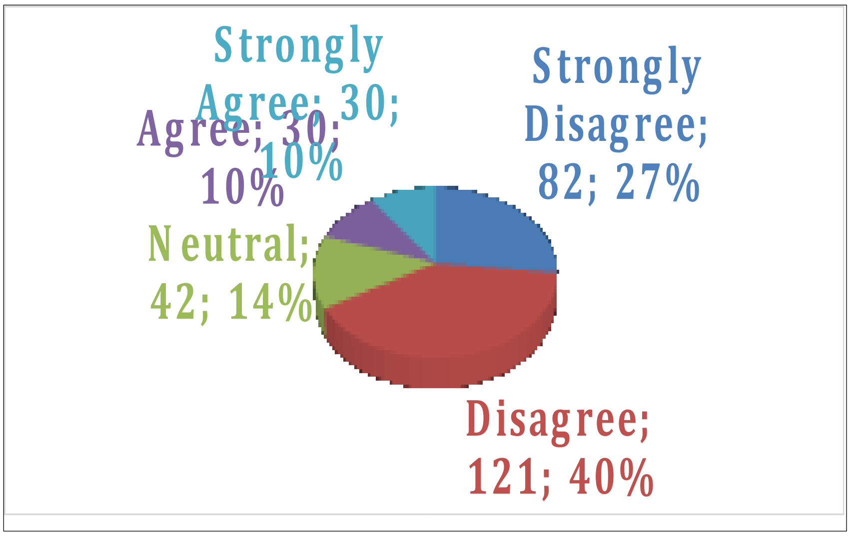

Figure 10 If all domestic electricity consumers invested in and implemented the recommended technology, ZESCO will not have to invest in new power station

Among the population, around 67% (40 agree and 27 strongly agree) believe that if all domestic electricity consumers invested in and implemented the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity, Zesco would not have to invest in new power stations.

Among the interested population, almost 53% (8 % strongly disagree and 45 % disagree) don't believe that investment in the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity can sensibly contribute to the effective operation of manufacturing industries.

When asked if investment in the recommended technology for alternative energy for heating, energy-efficient lighting, and powering electronic gadgets, or other models for serving electricity by domestic electricity consumers will improve the standard of living for all, 31% strongly agreed, 23% agreed, 22% strongly disagreed, 10% disagreed, and 14% were neutral.

5. Conclusion

The essence of this study was to enhancing energy saving behaviours of domestic electricity consumers, as a demand-side management model in Zambia.

The study analysed how the electricity-saving behaviours of domestic electricity consumers in Zambia can be enhanced as a demand-side management strategy for mitigating load shedding to balance demand and supply due to the electricity deficit in Zambia. The study was aimed at determining an appropriate demand-side management model for enhancing electricity saving behaviour, as a strategy for minimising the impact of using load shedding due to electricity deficit, and also as a contribution towards mitigating the impact of climate change.

According to the study findings, the electrical practitioners support the idea of utilising a suitable demand side model that has features for firstly, sufficiently warning the individual domestic householder of his or her overdrawing of electricity beyond the limit set by the supply authority and secondly, load shedding only those consumers consuming excess electricity and are not willing to comply with the appeal to "switch and save, as power saved is power share", and finally, a provision for resetting back to supply upon isolating the loads consuming excess power, in the event that the household was load shaded. According to the study that was conducted by the Energy Regulation Board, the inconvenience of load shedding was the reason many households started using LPG as an alternative source of energy for heating and cooking. The fear of being inconvenienced by load shedding has been used in this study to motivate households to use LPG as an alternative to electricity for heating and cooking.

This recommended demand-side model for enhancing electricity-saving behaviours of domestic electricity consumers is aligned with the Fogg Behaviour Model. It uses load shedding as a motivation factor to switch to LPG as an alternative source for heating and cooking, and the alarm as both a warning system against overdrawing of electricity by the individual domestic householders and as a triggering effect to enhance the domestic electricity consumers to "switch and save" electricity. The act of "switch and save" is a physical effort that is simple enough to be performed and is within the ability of the domestic electricity consumers to comply with. It is also in line with persuasive technology, which is intentionally designed to change people's attitudes or behaviour. The act of "switch and save" does not require high cognitive capabilities, more financial resources, a lot of time to be affected, or so much physical effort, and it does not disrupt routine life patterns.

Besides that, this recommended demand side model for enhancing electricity-saving behaviours of domestic electricity consumers operates on the principles of B.F. Skinner's Reinforcement Theory of Motivation, where positive punishment as the desirable stimulus is introduced to discourage the unwanted behaviour and negative reinforcement, as the undesirable stimulus is removed to encourage the required behaviour. The model's characteristic of "discriminatory load shedding" against domestic consumers who do not comply with the "switch and save" campaign would be used both as a "punishment" to prevent the unwanted behaviour of not complying with ZESCO's campaign to use electricity prudently, and also as a "reward" for those complying to the "switching and save" campaign of using alternative sources of electricity for heating and cooking such as LPG. From the study results, it is very evident that implementing such a demand-side model can enhance the electricity-saving behaviours of domestic electricity consumers and would contribute immensely towards improving the balance of demand and supply of electricity, reducing the impact of using load shedding as a demand-side management model, and as a mitigation measure against climate change in the country. Eventually, ZESCO's slogan, "switch and save, as power saved is power shared", would be realised.

The responses also showed that some householders needed to learn how to use alternative energy sources, such as solar energy and LPG for lighting and heating, as electricity-saving strategies for reducing electricity load shedding. This shows the need to sensitise domestic electricity consumers on electricity-saving strategies and their importance in alleviating chronic load shedding due to an electricity shortage. This was confirmed by how the respondents were responding. Furthermore, some respondents indicated that domestic electricity consumers need to be sufficiently motivated to use LPG as an alternative energy source for heating and cooking. Therefore, it is necessary to motivate these householders to invest in electricity-saving technology and compel them to improve their electricity-saving behaviour using appropriate demand-side managing models.

If effectively implemented, the demand side model for enhancing behavioural change for domestic electricity consumers would provide for enhancing a culture of prudent use of electricity, achieve the slogan of "switch and save, as power saved is power shared", ensure a steady supply of power, and a balance between demand and supply of electricity, drastically reducing the social-economic impact of load shedding, and contributing towards mitigation the impact of climate change.

Recommendations of the Study

Various gaps in the implementation of the "switch and save" campaign was identified in the study. A remote electrical load management system has been recommended as a possible model for alleviating the electricity load shedding due to an electricity shortage and enhancing the electricity-saving behaviours of domestic electricity. To implement and actualise this demand-side model, the Energy Regulatory Board, ZESCO and the Government of the Republic of Zambia (GRZ) should implement recommendations that have been advanced from the study.

- The Ministry responsible for Energy should create a Directorate and a government agency to develop and implement energy saving master plan with specific goals to achieve Energy Security, to drive the government policy dealing with energy security, particularly coordinating activities with various institutions, and to the extent possible champion the immediate intervention of an appropriate demand side management model, as one of the top list of government priorities.
- The project financing model is where the lender's recourse is primarily to the project's revenue stream rather than the balance sheet. In this model, a financer should create the Special Purpose Vehicle, or Project Company, which should be able to use the 2% Government Excise Duty on monthly electricity bills of ZESCO's customers as Equity for the Loan Scheme for Government programs of financing of high upfront costs, such as providing domestic electricity consumers with electricity-saving equipment to implement the Electrical Saving Project.
- The Ministry and agencies responsible for informing the nation should, within their mandates, embark on a sensitisation campaign to inform the nation of the importance of implementing electricity-saving measures and how each domestic electricity consumer can reduce load shedding.
- A suitable demand side model that sufficiently warns the individual domestic householder of overdrawing electricity and load shedding individually or severally only those consumers consuming excess electricity and is not willing to comply with the appeal to switch and save, as power saved is power share, should have the following features

A supply authority control centre for sending custom-coded instructions for actuation. A programmable remote terminal unit installed at a consumer's premises as part of the domestic installation would receive encrypted custom code instructions for its operation. A two-way communication medium infrastructure between the supply authority's control centre and the consumer-based remote terminal unit

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Compliance with ethical standards

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Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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Appendices

Appendix a 1; Block diagram for the model for enhancing energy saving behaviors for domestic electricity consumers

The Model

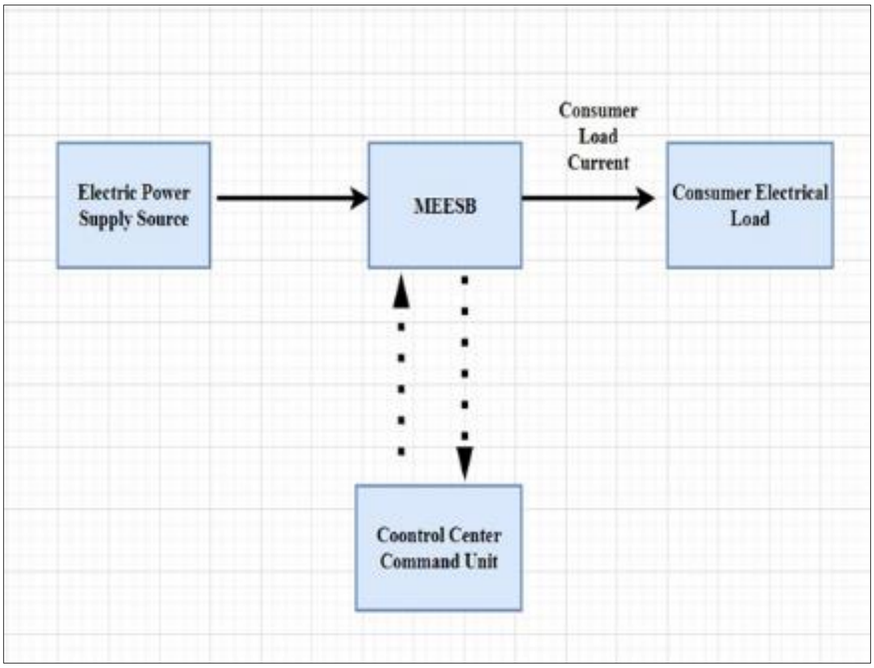

Figure A Block diagram for MEESB

Appendix a 2; Block diagram for losed-loop control system for the model for enhancing energy saving behaviours for domestic electricity consumers

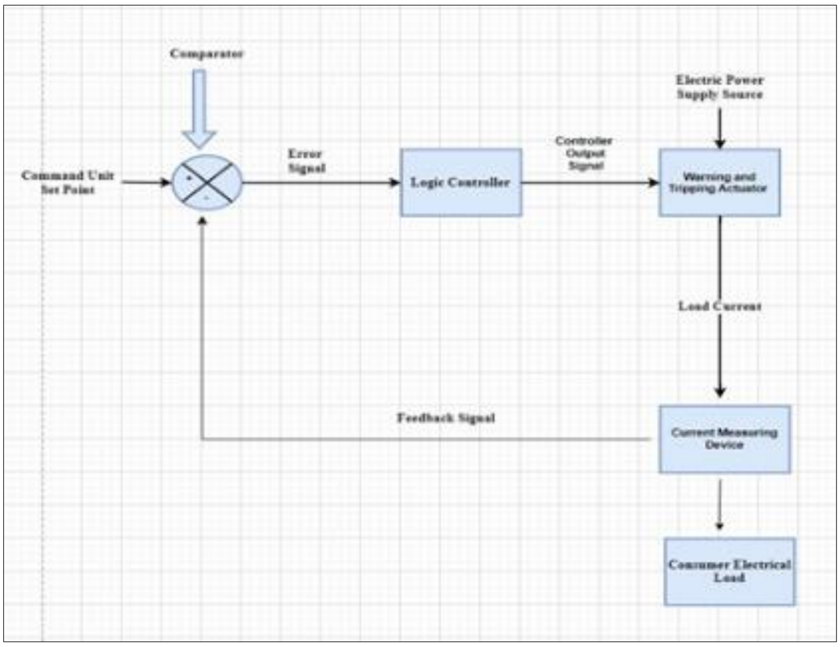

Figure B Source: Bartelt (2002) Block diagram for closed-loop control system