Interest in Solar Photovoltaic (PV) and Peer-To-Peer Energy Trading for Backup Electricity in Nigerian Residential Housing Estates

AYOOLUWA OLUSOLA ADEWOLE

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy in Energy Economics and Policy

Bartlett School of Environment, Energy and Resources

UCL Energy Institute

University College London

December 27, 2022

DECLARATION

I, AYOOLUWA OLUSOLA ADEWOLE, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Solar energy presents a highly viable alternative for backup electricity provision in urban Nigeria, as the technology is now mature. Due to widespread electricity blackouts, petrol and diesel generators are widely used, causing local air and noise pollution and contributing to climate change. However, the main clean alternative, solar, has little foothold in the Nigerian energy market. The thesis explores whether households value the “clean power” benefit of the widespread adoption of solar energy for backup electricity in residential estates. It employs a mixed-method approach using semi-structured interviews, a survey, and a discrete choice experiment with 649 respondents in Ibadan, a Nigerian city, to provide insights into preferences for clean and quiet solar PV backup electricity on a residential estate as well as energy trading preferences. Applying quantitative and qualitative methods, the study finds that consumers are interested in dwelling in estates that only permit cleaner backup alternatives, including solar and inverters, compared with the status quo option of staying in estates with petrol or diesel generators. The study also finds that consumers are interested in peer-to-peer energy trading, with differences in preferences for selling and buying excess electricity from neighbours. The thesis also finds that autarky aspirations and financial benefits are key factors that influence participation in energy trading. The findings demonstrate that whilst the electricity supply remains unreliable, there is an opportunity for solar PV to claim a much larger share of the backup electricity market. Furthermore, policymakers and clean energy providers keen to increase the uptake of residential solar energy should highlight the clean and quiet benefits of solar energy for the residents themselves. This research also demonstrates an opportunity to develop and market clean, quiet estates that appeal to people concerned about the health impacts of generator use.

IMPACT STATEMENT

This thesis investigates the preferences and choices of individuals and households for solar PV as a form of backup electricity and preferences for engaging in peer-to-peer energy trading. The findings in this research have a potential impact within and outside academia.

This thesis contributes to the academic literature by analysing consumer preferences for solar PV as a home attribute focusing on local benefits to residents. Furthermore, this thesis also contributes to the literature on preferences for solar by providing a fresh perspective on solar-PV as a form of backup electricity rather than focusing exclusively on it to facilitate the clean energy transition. The use of choice experiments to study preferences for backup energy and solar energy in Nigeria is also novel. This study contributes to an emerging evidence base on the potential economic and social value of peer-to-peer energy trading by outlining the possible financial benefits and energy independence afforded by peer-to-peer energy trading.

Outside academia, there are some potential impacts of this research in developing strategies to increase the uptake of Solar PV and innovative peer-to-peer Energy trading technology. The findings can inform residential estate developers that potential purchasers are keen on clean and quiet estates that ban the use of noisy and air-polluting generators and keen on estates that enable them to engage in peer-to-peer energy trading. The findings have been summarized and disseminated to the Nigerian Institution of Estate Surveyors and Valuers (NIESV).

The findings in this research have been circulated to a broader audience within and outside academia. The results of this thesis have also been summarised in two research papers submitted to relevant peer-reviewed journals for publication. I have also presented results from this thesis at academic conferences and a PhD summer school. In addition, the key findings of this thesis have been disseminated to industry partners, notably bp, who partly funded the PhD.

The knowledge I have acquired throughout my PhD provides me with essential expertise for my career goals. For example, the expertise gained during the PhD has informed my work at the World Bank Group. During my time as an African Fellow at the private sector arm of the World Bank, the International Finance Corporation, I was a contributor to four chapters of a report on the role of the private sector in power markets globally. I contributed case studies on clean energy and innovative technology models like peer-to-peer energy trading to provide electricity access in other developing countries like Nigeria. In another role as an African and African Diaspora Infrastructure Fellow at the World Bank, I have also applied expertise gained from my PhD to inform the design of power sector projects in other developing countries, including a project that incorporates battery storage technology to the power grid.

ACKNOWLEDGEMENTS

First, I give all the glory to my Lord and Saviour, Jesus Christ, the author and finisher of my faith.

I would like to express deep gratitude to my darling wife, Abimbola Ifeoluwa, who has supported me throughout this journey. Your patience when listening to me routinely bring up solar energy in Nigeria has kept me going. You have been my rock, helped me through this journey, and helped me through the challenges I have faced.

I would also like to thank my family for their immense support. Without my parents, Engr. Adekanmi Adewole and Dr Adekolarin Adewole, my siblings, Ibukun, Olamide and Eniife, and my Aunty, Mope and Uncle Yomi Akintorin, I would not be who I am today.

I am grateful to my supervisors, Michelle Shipworth, Xavier Lemaire, and Danielle Sanderson, for their advice and guidance throughout the past years. I particularly thank Michelle, who went above and beyond to ensure my time at UCL made me a better person. You have been patient with me, helped me through lows and supported me to reach heights I could only dream of. For this and much more, I cannot thank you enough.

My gratitude goes to Prof. David Shipworth for introducing me to the subject of peer-to-peer energy trading and for his intellectually stimulating research methods lectures. I would like to thank bp for funding my PhD research. I thank Prof. Adeola Adenikinju for inspiring me to become an energy economist. Meeting him in 2012 at the Nigerian Association for Energy Economics Conference in Abuja changed my career trajectory. I am forever grateful for the opportunity to work with and learn from him. I am thankful to Dr Ciro Avitable, who inspired me to do a PhD to achieve my dream of working at the World Bank.

I would also like to thank UCL Energy Institute colleagues and my friends Adesola and Oyin Sunmoni, Nandi Mbazima, Muez Ali, Suneina Jangra, Lilia Caiado, Joe Lambert, Kentaro Mayr, Femi Eludoyin, Ayomide Oluseye, Mary Agyapong, Sarah Aramide, Damilola Adeyemi, Lanre Kassim, Temitope Laniran and Sheriff Badmus for their support, stimulating discussions and encouragement.

Furthermore, I am grateful to UI-LISA, a statistical laboratory at the University of Ibadan, for their support during my field work survey in Ibadan.

Finally, I would like to thank my examiners Prof. Yacob Mulugetta and Dr Marije Schaafsma, for their constructive feedback during my PhD defence.

DEDICATION

I dedicate this thesis to my daughter, Oluwatamilore Anne, whose birth has given me the strength to complete this PhD.

You can achieve anything you set your mind to as God strengthens you.

TABLE OF CONTENTS

List of Figures

List of Tables

List of Acronyms

AE	Averting Expenditure
AIC	Akaike Information Criterion
ASA	Alternative-Specific Attribute
ASC	Alternative Specific Constant
BDCE	Binary Discrete Choice Experiment
BIC	Bayesian Information Criterion
CE	Choice Experiment
CL	Conditional Logit
CV	Contingent Valuation
DCE	Discrete Choice Experiment
ESMM	Exploratory Sequential Mixed Methods
EV	Electric Vehicles
GRAs	Government Reserved Areas
GW	Gigawatt
IBEDC	Ibadan Electricity Distribution Company
ICS	Improved Cookstoves
ICT	Information and Communication Technology
IIA	Independence of Irrelevant Alternatives
IPPs	Independent Power Producers
IRENA	International Renewable Energy Agency
LCL	Latent Class Logit
LISA	Laboratory for Interdisciplinary Statistical Analysis
LR	Likelihood Ratio
ML	Mixed Logit
MNL	Multinomial Logit
MW	Megawatt
MWTP	Marginal Willingness to Pay
MXL	Mixed Logit Model
NDC	Nationally Determined Contribution

NEPA	National Electricity Power Authority
OECD	Organization for Economic Co-operation and Development
P2P	Peer-to-Peer
PM	Particulate Matter
PV	Photovoltaic
RE	Renewable Energy
REA	Rural Electrification Agency
RET	Renewable Energy Technology
RP	Revealed Preference
RPL	Random Parameters Logit
RUT	Random Utility Theory
SD	Standard Deviation
SDG	Sustainable Development Goals
SHS	Solar Home System
SP	Stated Preference
UI	University of Ibadan
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WTP	Willingness to Pay

1. CHAPTER 1: INTRODUCTION

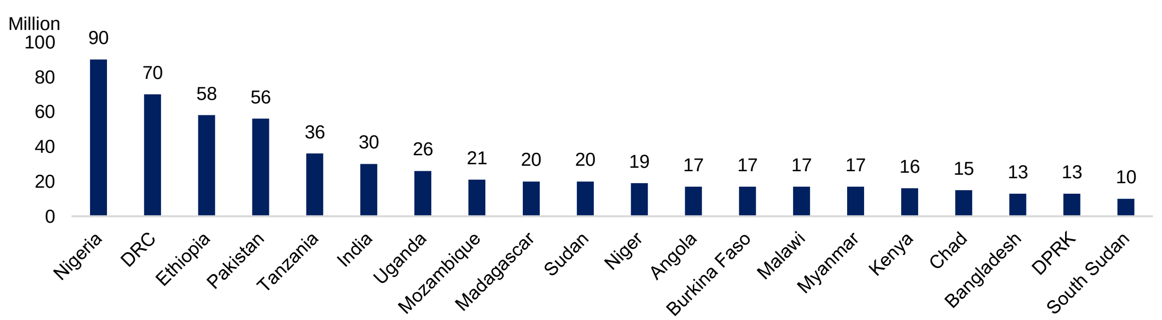
Chapter Overview

This chapter provides an introduction and sets the study's context and motivation. The context focuses on the multifaceted electricity problems in Nigerian cities and the potential role of decentralized renewable energy (RE) in solving these problems. The chapter also provides a rationale for the study by presenting the case for ‘green’ residential estates where backup energy generation is through solar PV systems instead of diesel and petrol-fired generators. In addition, it also presents the case for energy exchange among residents in such estates. The remainder of chapter 1 outlines the research questions, objectives and scope. It also presents readers with the main findings from the study and a structure for reading the thesis. Finally, this chapter provides a layout that serves as a guide for reading the thesis.

1.1. Context and Rationale for the Study

Three key energy policy goals in developing countries are energy access, reliability, and sustainability. Despite progress made in the past decade with the United Nations Sustainable Development Goal (SDG) 7 to ensure access to affordable, reliable, sustainable and modern energy for all, with more than one billion people gaining access to electricity globally, there is still a large access deficit in Africa (World Bank, 2021b). In 2019, eight of the top ten countries with an electricity access deficit globally were in Africa (See Figure 1-1 below). In Sub-Saharan Africa alone, about 570 million people are still without access to electricity, and the top three countries with the highest number of people without access are in Africa.

Figure 1-1: Population without access to electricity of top 20 access-deficit countries (million)



Data source: World Bank (2021b)

Inadequate electricity access in Sub-Saharan Africa is a constraint on the quality of life for residents in the region, as they cannot enjoy the benefits full access to electricity brings in terms of public service provision. Indeed, public service in areas such as municipal services is limited due to inadequate electricity access, with effects on the provision of properly lit streetlights and innovative technology adoption in areas such as healthcare, education, and agriculture, amongst others. The access rate on the continent (48 per cent) lags behind other regions (global average of 90 per cent in 2020). This number of people without access on the continent has risen in recent decades, as the access rate has been outstripped by rising population growth. In rural parts of sub-Saharan Africa, the access rate of 29 per cent is much lower than the global average of 83 per cent (WDI, 2022)

Furthermore, the literature has shown linkages between electricity demand and access constraints. Evidence from a study by Blimpo, Postepska and Xu (2020) shows that a significant portion of the access gap in 31 African countries can be accounted for by factors related to electricity demand on the continent. These demand gaps can constrain investment, given the challenges with the financial viability of electricity access. Inadequate access to power often leaves households and firms with long hours of brownouts, which affects the potential utilisation of electricity by end-users. Several African countries have reliability challenges with countries. As of 2014, countries such as Nigeria, Ghana, Liberia and Guinea had about half of households without any electricity supply, despite having a grid connection (Blimpo and Cosgrove-Davies, 2019). Improved reliability of power on the continent can aid the uptake of electricity as reliability improvements would encourage productive use of electricity and attendant economic benefits.

The importance of reliability, capacity, and durability of off-grid electricity solutions is also crucial to household uptake. Policy-wise, although consistent progress has been made since 2019, many countries in Sub-Saharan Africa are still without advancements in policies and regulations to improve access as of 2021. Two notable exemptions on the continent are Nigeria and Ethiopia, the two largest energy access-deficit countries (World Bank, 2022). These countries have made policy progress with the adoption of policy and regulatory measures on electrification planning, frameworks for mini-grids and off-grid systems, and consumer affordability of electricity. Against this backdrop, this thesis investigates the adoption preferences of consumers in Nigeria for off-grid solutions, notable solar PV and Peer-to-Peer (P2P) energy trading, as would be outlined further in this chapter.

1.2. Access to Electricity in Nigeria

In Nigeria, people without access increased from 83 million in 2010 to 90 million in 2019, representing 12 per cent of the global access deficit. Most households connected to the power grid experience daily outages and frequent voltage fluctuations, relying on diesel and petrol-fired generators and rechargeable batteries to meet electricity supply needs (World Bank, 2020a).

During the COP26 discussions, Nigeria announced plans to reach net zero by 2060 (Climate Action Tracker, 2021). This new target is aligned with the government's revised Nationally Determined Contribution (NDC) submission to the United Nations Framework Convention on Climate Change (UNFCCC) in July 2021. The revised NDC included plans to eliminate diesel and petrol generators for electricity generation by 2030 and use 13 GW off-grid RE, including mini-grids and solar home systems (FGN, 2021). The achievement of these targets will require increased scale-up of RE sources and associated battery storage. As solar PV and battery prices are expected to decline rapidly, innovative digital technologies are needed to integrate renewables further (IEA, 2020).

1.2.1. Generator Use in Nigeria

Erratic grid supply has led to reliance on self-generation through backup (diesel and petrol-fired) generators to meet electricity demand. Challenges associated with using these generators include high running costs as they need to be constantly fuelled. Running these generators is estimated to cost 6 to 10 times more than paying for grid-supplied electricity (Radwan and Pellegrini, 2010). The REA (2017)[1] estimated that

[1] In conjunction with the World Bank and Rocky Mountain Institute (RMI)

Nigerians spend $14 billion annually on inefficient generation, primarily through these generators.

The generators also lead to noise and environmental pollution, contributing to climate change due to the carbon emissions associated with them[2]. There are also fire, safety and health risks from these generators' exhaust fumes (Vanguard Newspaper, 2013). Diesel exhaust fumes contain toxic substances such as particulate matter (PM) 2.5, benzene, arsenic and formaldehyde (Awofeso, 2011). The particles from diesel exhaust are tiny enough to penetrate deep into the lungs resulting in various health effects ranging from irritation of the nose and eye to swollen airways, headache, fatigue, nausea and respiratory changes (Gulati, 2010). Such exposure can also lead to chronic effects, including cardiovascular diseases, respiratory diseases and lung cancer (Brook et al., 2010; Benbrahim-Tallaa et al., 2012; Silverman et al., 2012; WHO, 2012). In Nigeria, there is growing evidence of the effect diesel exhaust has on the incidence of lung cancer and declining lung function among non-smoking urban generator users (Salami, Adeoye and Adegboye, 2010; Awofeso, 2011; Iyogun, Lateef and Ana, 2018). The HEI (2018) also pointed out a high outdoor concentration of particulate matter in Nigeria, above the World Health Organization (WHO) guideline[3] for healthy air.

Constant exposure to excessive or repetitive noise over a sustained period (such as exposure to sounds above a range of 70-75 decibels) can also result in health problems such as loss of hearing, hearing dysfunction, high blood pressure, sleep deprivation and abnormal development of unborn children (Selander *et al.*, 2016). Studies conducted in Northern, Eastern, Southern and Western Nigerian cities reveal that indoor and outdoor sound levels from generator use often exceed the WHO acceptable limits of 70dB(A) for regular discussions and 30dB(A) for sleeping and resting

[2] Moss and Gleave (2014) estimate that generator use in Nigeria produces 29 million metric tons of CO_2 annually.

[3] The WHO set the Air Quality Guideline for annual average PM2.5 concentrations at 10 $\mu g/m^3$ based on evidence of health effects of long-term exposure to PM2.5. The WHO also suggested three interim targets set at progressively lower concentrations: 35 $\mu g/m^3$, 25 $\mu g/m^3$, and 15 $\mu g/m^3$. As at 2016, annual average PM2.5 concentrations in Nigeria were estimated at 122 $\mu g/m^3$, one of the highest globally (HEI, 2018).

(Mbamali, Stanley and Zubairu, 2012; Menkiti and Agunwamba, 2015; Onwuka, Ezigbo and Eneche, 2017; Giwa, Nwaokocha and Adeyemi, 2019; Heinemann *et al.*, 2022). Generator use in Nigeria has also been linked to psychosocial and behavioural problems, including quarrels/verbal confrontations leading to fractious/tense relationships between generator users and their neighbours (Yesufu, Ana and Umar, 2013; Osagie *et al.*, 2016). In addition to reducing the quality of life, air pollution also has adverse effects on economic outcomes, including loss of productive labour, income and productivity and reducing the competitiveness of cities. (Narain *et al.*, 2016).

There is a growing debate on banning the importation and use of generators in Nigeria. Some residential estates have started to impose restrictions on generators in the country, such as when they can be used (Alao, 2018). Oseni (2016) contributed to this debate by examining the policy question regarding government banning or encouraging self-generation. However, the study was limited to household preferences for dispensing with generators as a source of backup electricity and did not consider the use of alternative sources of backup energy such as solar PV. There is a need to further investigate the preferences of Nigerian households for using solar PV as a source of backup power instead of generators, considering the negative externalities that arise from generator use.

Furthermore, due to fuel scarcity which occurs from time to time in Nigeria, the security of supply for diesel and petrol is not guaranteed. These periods of fuel scarcity often result in consumers buying petrol at much higher unofficial market[4] prices to meet their energy needs (Al Jazeera, 2017; The Nigerian Tribune, 2017). There are also instances of voltage disturbances or collapses associated with electricity supplied via the grid resulting from generation sources located remotely from Nigeria's load centres (Somefun, 2015; Adetokun, Ojo and Muriithi, 2021; Jacal *et al.*, 2022).

Firms are not left out as a World Bank (2016) survey showed that 80 per cent of Nigerian companies count electricity as a significant constraint to growth. Continued

[4] Otherwise known as the “black market”.

reliance on generators[5] to power electricity supply contributes to the extraordinarily high cost of doing business in Nigeria. In 2015 an average manufacturing firm in Nigeria lost about 17 per cent of its sales due to power outages compared to less than one per cent for firms in China, South Africa and Russia and five per cent for those in Ethiopia (Buba *et al.*, 2016).[6]

1.2.2. Solar Energy in Nigeria

Solar energy presents a viable alternative for urban energy consumers in Nigeria to meet their electricity needs. Firstly, there is a vast abundance of solar radiation all around the country due to its position on the equator, with an annual daily average of total solar radiation in the country ranging from 3.5–7.0kWh/m^2 (Ohunakin *et al.*, 2014). Studies have also shown that solar power has the potential to provide access to clean energy in Nigeria, where the traditional grid has not been able to provide stable electricity (Adurodija, Asia and Chendo, 1998; Bugaje, 1999; Adeoti, Oyewole and Adegboyega, 2001; Oparaku, 2002, 2003; Ohiare, 2014; Ohunakin *et al.*, 2014; Ugulu, 2016; Elegbede *et al.*, 2021).

Secondly, when compared with diesel generators on a lifetime basis, solar PV systems are already cost-competitive in Nigeria, costing an average of $0.20 per KWh[7] in comparison to diesel generators, which cost an average of $0.30 per KWh (Roche, Ude and Donald-Ofoegbu, 2017, p. 23). If solar prices continue to fall globally (Bloomberg New Energy Finance, 2017, 2020), solar energy in Nigeria could be cost-competitive with the grid.

Thirdly, being a renewable form of energy, it does not contribute to climate change; rather, it aids in mitigation efforts. Additionally, using solar energy to meet electricity

---

[5] For example, as at 2007, Nigeria's Largest Telecoms company, MTN spent about $66m annually on diesel to fuel 6,000 generators at its base stations, a figure which might have increased due to expansion over time. (Daily Trust, 2007)

[6] However, the scope of this study is limited to households and not firms due to the focus on the benefits households derive from collective adoption

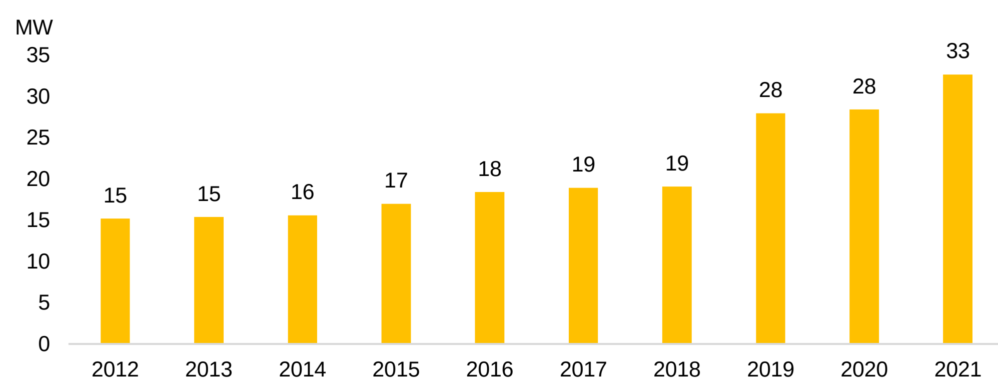
[7] Including costs for battery storage.

demand aligns with the Nigerian government's policy target to contribute 30 per cent to on-grid generation capacity by 2030 (FGN, 2016). The technology also addresses the noise and air pollution risks associated with backup generators. It reduces the health, fire and safety risks related to backup generators as it does not involve the combustion of highly flammable fuels such as diesel and petrol. Nowadays, smart meters accompany solar home systems, which means they can be used to address the challenge of inadequate metering associated with electricity supplied through the conventional grid.

1.2.2.1. *Barriers to solar PV adoption in Nigeria*

However, despite the established evidence of the country's vast solar energy potential, adoption in the country has been slow. As of 2018, solar PV accounted for less than one per cent of Nigeria's installed electricity capacity (IEA, 2018). Between June 2015 and 2020, only 1.2 million small-scale solar products were sold[8]. In 2021, only about 33MW of solar PV capacity was installed in the country, up from 15MW in 2013 (see Figure 1-2).

Figure 1-2: Installed Solar PV capacity (MW) in Nigeria



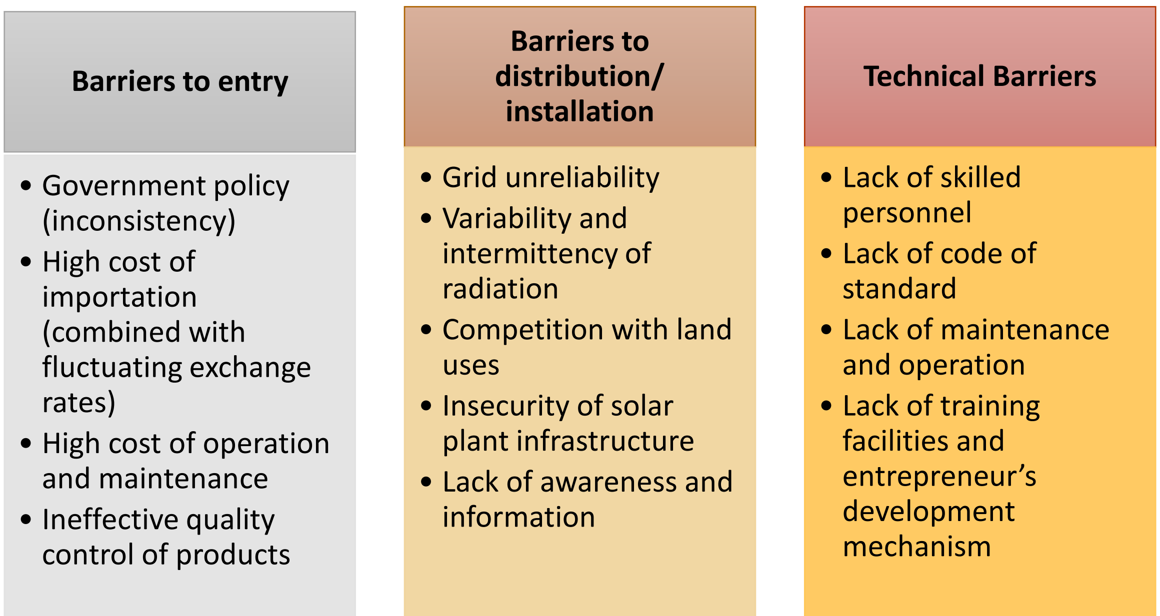
Source: IRENA (2022)

The reasons usually cited for consumers in Nigeria being unwilling to adopt solar energy as an alternative to their erratic grid supply and backup generators include high upfront costs and substandard products, eroding consumers' confidence in the technology (Ohunakin *et al.*, 2014; Thompson, 2021). Other factors include technical

[8] Estimated based on Global Off-Grid Solar Market Reports (Sales and Impact Data) between 2015-2020 from GOGLA, 2021.

barriers and challenges with the widespread availability of skilled personnel for adequate installation, maintenance, and operation (Ugulu and Aigbayboa, 2019; Olanite and Nwohu, 2022). Similarly, solar adoption in the country is stymied by sociocultural factors arising from limited awareness by the general public about the benefits of solar PV and public resistance to new technology, especially as it relates to its efficiency (Anugwom, 2022). A wide range of financial, distribution, installation and technical barriers to solar energy adoption in Nigeria is summarized in Figure 1-3 below.

Figure 1-3: Barriers to Solar PV adoption in Nigeria



Source: Adapted from Netherlands Enterprise Agency (2021)

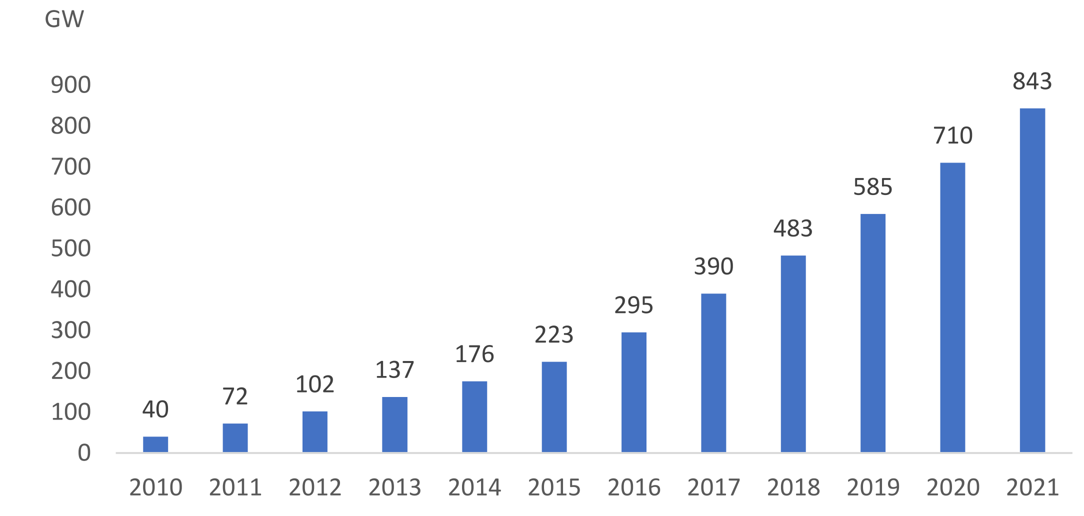
Utility-scale solar has been stymied by policy uncertainties, with delays from renegotiations to previously awarded Power Purchase Agreements (PPAs) resulting in project delays (IEA, 2021). The renegotiations are due to disputes between the government and the Independent Power Producers (IPPs) on the PPA tariff structure. The IPPs agreed on PPA tariffs at US$0.115 per kWh. However, the government is insisting on a tariff of US$0.075 per kWh, citing declining solar costs and comparable projects in countries such as Senegal (US$0.05/kWh) and Zambia (US$0.06/kWh).

1.2.3. The role of decentralised energy solutions

Grid extension and off-grid/decentralised energy are two leading solutions explored to achieve the 2030 electrification objective: Highlighting the importance of off-grid solutions, the (IEA, 2011) estimated that extending the grid to rural areas will cater to only 30 per cent of the population to be covered, while 70 per cent will be served by off-grid or mini-grids systems. Like rural areas, electrification challenges are also present in urban and peri-urban areas, as urban residents also need electricity to meet household needs (Broto *et al.*, 2017). Szabo *et al.* (2011) found that in many parts of Africa, the cost of decentralised off-grid options can be cheaper than extending the grid using a spatial least-cost analysis framework. Bazilian *et al.* (2012) also suggested that off-grid supply systems based on diesel generators or solar PV systems will be vital to provide universal primary electricity access.

Solar energy is one of the decentralised RE sources increasingly used to provide electricity access. Globally, solar PV installations have risen, reaching 843 Gigawatt (GW) in 2021, up from 40 GW in 2010 (see Figure 1-4). This rise is attributed to various reasons, such as falling costs and technological advancements (solar PV, battery storage and information and communications technology (ICT)). Other causes include deeper penetration of mobile telecommunication technology, increased emphasis on generating energy through renewable and sustainable means, and global efforts to mitigate climate change. However, the growth is mainly concentrated in the OECD countries and non-OECD countries like China. It is widely expected that distributed solar power and storage will have a significant role in the energy transition, with considerable energy growth in non-OECD countries (IEA, 2020). In Africa, low-carbon decentralised energy technologies like solar are poised to play a role in electrifying communities across the continent (Sokona, Mulugetta and Gujba, 2012; Kılıç and Kekezoğlu, 2022), with access providing potential benefits in education, health, job creation, and gender, amongst others (Mulugetta, Ben Hagan and Kammen, 2019).

Figure 1-4: Global Solar PV Installed Capacity (GW)



Source: IRENA (2022)

1.2.4. The Case for Having Estates with Solar PV Systems for Backup in Nigeria

As well as offering global environmental benefits, solar PV provides local environmental benefits compared to current sources of backup electricity in Nigeria, where blackouts are widespread. In urban estates where generators are restricted, homes can collectively adopt solar PV as their backup electricity source. By adopting solar energy, residents can enjoy benefits such as reliability, clean air and serene environments, provided the adoption is carried out collectively, such as in neighbourhoods where generators are restricted. This case is an alternative to the present situation where homeowners using solar energy do not fully enjoy the benefits of clean air and quiet environments. Instead, they suffer negative externalities as their neighbours can still use polluting generators (Oseni, 2016). Some studies in the literature have discussed this collective action problem in the energy sector (e.g. Goedkoop and Devine-Wright, 2016; Koirala *et al.*, 2018; Eslamizadeh *et al.*, 2020).

1.2.5. The emergence of peer-to-peer trading in the energy sector

P2P energy trading of solar energy among residential energy consumers is an innovation that can potentially enable the uptake of solar energy to address energy access, reliability, and sustainability challenges. In recent years, the P2P energy trading business model, where energy consumers and producers trade electricity directly without an intermediary (IRENA, 2020), has emerged as an innovative model for decentralised energy transactions. In this model, electricity is traded in a decentralised manner between buyers and sellers on a platform (which can be based on blockchain technology), and trading occurs when demand matches supply. P2P energy trading centres on the notion of energy "prosumers" who can simultaneously produce, consume, trade, and share energy directly (Zhou *et al.*, 2020). The P2P energy trading model can be deployed among neighbours within local communities like residential estates via the distribution grid or a mini-grid (Einav, Farronato and Levin, 2016; Zhang *et al.*, 2017). Alternatively, numerous communities can deploy the model in large-scale settings, where small groups of communities or mini-grids trade electricity among themselves, enabled by interconnected networks owned by distributed system operators.

1.2.5.1. *Benefits of P2P energy trading*

The P2P energy trading model offers several benefits. P2P energy trading can improve the deployment and flexibility of RE and empower consumers to use their distributed energy resources better. In the context of a standalone mini-grid, P2P energy trading can improve energy access and reliability of local RE sources. For example, the P2P model has been successfully piloted in Bangladesh by SOLshare, a private company, whereby households are interconnected through a low-voltage direct current grid. Power flow in this system is controlled through bidirectional metering integrated with an ICT back-end that handles payment, customer service, and remote monitoring. These smart meters allow users to trade electricity generated from renewable sources with neighbouring consumers (households, businesses, and rural industries). As a result, prosumers in this setting have gained access to electricity and earned additional income by selling their surplus electricity (UNFCCC, 2020).

Decentralised P2P energy trading can provide a platform for flexible trading and payments for RE (Mengelkamp *et al.*, 2017; Orcutt, 2017). Using a blockchain-based platform for such decentralised P2P energy trading transactions can also reduce transaction costs by eliminating the need for an intermediary (Esmat *et al.*, 2021). P2P energy trading can also prove helpful in settings where individuals are motivated by desires to share electricity instead of economic gains from trading energy (Hackbarth and Löbbe, 2020). Furthermore, P2P energy trading allows prosumers to provide excess solar PV to other consumers through donations or at a reduced cost (Karami and Madlener, 2022). In providing access to energy for financially constrained people, these reduced transaction costs and the ability to supply excess electricity at a lower price can be beneficial.

P2P energy trading also contributes to electricity system resilience to emergency outages (Tushar *et al.*, 2019). Furthermore, P2P energy trading markets can lead to new Business-to-Consumer business models for electricity that take account of consumer preferences and interests (Sousa *et al.*, 2019). Other advantages include balancing supply and demand and congestion management through efficient integration of distributed RE resources and provision of ancillary services to the power grid (Zhang *et al.*, 2018).

Some other benefits of P2P energy trading include the potential cost-saving benefits for consumers, as they can buy electricity directly from a prosumer (Andoni *et al.*, 2019; Brown, Woodhouse and Sioshansi, 2019; Morstyn, Teytelboym and McCulloch, 2019a). Closely related is the potential for improved energy security at the household level, as P2P energy trading can help to diversify the energy mix of a household in grid-constrained settings with unreliable electricity and reduce the risk of blackouts or other disruptions (Morstyn, Teytelboym and McCulloch, 2019b; Oyekola, 2020). In addition, P2P energy trading can also further environmental sustainability by fostering the adoption of RE sources, as individuals and businesses can sell excess solar back to the grid, thus enabling residential consumers to trade surplus energy from RE like solar (Nguyen *et al.*, 2018; Brown, Hall and Davis, 2019; Neves, Scott and Silva, 2020; Karami and Madlener, 2022)

1.2.5.2. *Challenges with P2P Energy Trading*

There are several challenges with the adoption of P2P energy trading, which would need to be overcome for the technology to be widely adopted in a manner that can be beneficial. There are several barriers that can prevent the successful implementation of P2P energy trading, especially in a developing country like Nigeria.

First, P2P energy trading requires a robust and reliable electricity grid to facilitate the buying and selling of excess electricity (Bellekom, Arentsen and van Gorkum, 2016; Neves, Scott and Silva, 2020). However, many developing countries, like Nigeria, are plagued with unreliable electricity grids or, in some cases, non-existent, making it difficult to implement P2P energy trading. Second, P2P energy trading relies on advanced technology, such as smart meters and online platforms, to facilitate transactions (Morstyn, Teytelboym and McCulloch, 2019b; Okwuibe, 2019; Tushar, Saha, Yuen, Morstyn, *et al.*, 2020). In a developing country like Nigeria, access to this technology is still limited, making it difficult to implement P2P energy trading, as the country still faces challenges with effectively metering electricity consumers in the country (Arawomo, 2017; Dahunsi, Olakunle and Melodi, 2021; Soyemi *et al.*, 2021). Third, there are still regulatory challenges with P2P energy trading (de Almeida *et al.*, 2021; Schneiders, Fell and Nolden, 2022). In some cases, governments may be resistant to change or may have regulatory frameworks that are not conducive to P2P energy trading. In addition, many people wan developing countries may be unaware of P2P energy trading and how it works (Gunarathna *et al.*, 2022). This can make it difficult to build a critical mass of participants and make the system viable. Finally, developing countries may face challenges in securing financing to develop the necessary infrastructure and technology for P2P energy trading (Junlakarn, Kokchang and Audomvongseree, 2022). This can make it difficult to implement and scale P2P energy trading systems.

1.3. Research Questions

With developments in RE, such as standalone solar PV and battery storage systems providing scope for addressing some of the earlier outlined challenges with backup generator use in Nigeria, it is essential to understand the preferences of end-users. Such insights can inform further product development and the development of relevant policies and strategies to accelerate uptake. Similarly, with the emergence of P2P energy trading, it is vital to investigate factors influencing the participation of residential end-users. To this end, this study uses a mixed-method approach to answer the following questions;

- RQ1: What are the user preferences for solar PV as a form of backup electricity in a Nigerian residential setting?
- RQ2: What are the potential benefits that influence preferences for P2P energy trading among residential consumers?
- RQ3: To what extent can the characteristics of the decision-maker explain these preferences?

1.4. Key Contributions of the thesis

This study has several novelties. First, using a Discrete Choice Experiment (DCE) approach, as outlined in Section 3.6, addresses the need for more experimental studies in the RE field. As Grimm *et al.* (2017) conclude, there's a need for further experimental studies that can examine the mechanisms behind the take-up behaviour of solar PV in developing countries, including households' willingness to pay (WTP) for electric energy, among others[9].

Second, it is the first known attempt to investigate the preferences for solar as a form of backup electricity in Nigeria and the preferences for specific attributes of solar PV. This study complements the literature on consumer preferences for solar as a form of backup electricity in contexts where the grid is unreliable. Studies on preferences for solar PV, like Lemaire (2009), have shown that people are interested in using solar home systems (SHS) despite grid extension due to reliability concerns. This thesis,

[9] Others include the role of credit constraints, and information.

therefore, complements the literature by presenting a fresh perspective on the use of solar PV to provide backup electricity in contexts where grid electricity is unreliable.

Third, this study aims to contribute to the literature on the P2P energy trading of RE. This contribution is made by estimating the preferences of urban residents in Nigeria for engaging in energy trading and using clean backup energy employing the DCE approach. This contribution enriches the emerging literature on socioeconomic dimensions of P2P energy trading, which technology-based studies have primarily dominated. This study's contribution is also in line with the research agenda outlined by Broto *et al.* (2017) on the need for further understanding of the needs of urban energy users, using context-specific, disaggregated data and applied interdisciplinary research to identify how these needs can be met within present constraints.

Fourth, this study contributes to an emerging evidence base by examining the possible financial benefits and energy independence afforded by P2P energy trading; studies on this topic are necessary because they are limited. Moreover, the few studies conducted thus far have primarily been conducted in western developed countries. Therefore, this study's contribution is even more valuable; it presents evidence from a survey and choice experiment conducted in Ibadan, Nigeria's third-largest city in Africa's most populous country.

1.5. Thesis Structure

This thesis consists of six further chapters. In the following two chapters (Chapters 2 and 3), the thesis is situated in the context of similar literature and the research methodology is established. Chapter 2 reviews the existing literature on preferences for RE, P2P energy trading and WTP for RE. Relevant gaps in the literature are also identified to situate the research questions adequately. Chapter 3 discusses the research methodology and design, providing the philosophical foundations, study context, data collection methods, survey and questionnaire design, and a description of the techniques used to collect, analyse and present the data.

Chapters 4, 5 and 6 present results from the data analysis conducted. Chapter 4 details findings from an exploratory qualitative study and highlights how this influences the design of the subsequent quantitative analysis. It also discusses how the qualitative results explain the preferences of Nigerian residents for using backup energy and the attributes they look out for when deciding on a new home.

Chapter 5 presents the quantitative analysis of data from the discrete choice experiment. The chapter analyses individual preferences for attributes of solar energy using econometric models for discrete choice data. Chapter 6 outlines quantitative findings from the survey on preferences for energy trading. Specifically, this chapter examines how *financial benefits and independence aspirations* influence preferences for P2P energy trading in a residential estate setting.

The final chapter (Chapter 7) summarizes the study's main findings and the implications of findings for relevant stakeholders. The chapter includes a reflective evaluation of the study's limitations and presents an agenda for future research.

2. CHAPTER 2: LITERATURE REVIEW

Chapter Overview

This chapter reviews the existing literature on preferences for RE, P2P energy trading, and WTP for RE, emphasising studies using stated preference (SP) methods described in the methods section. To answer the research questions posed above, it is important to review evidence from the literature on preferences for energy, with a detailed look at preferences for renewable energy and solar in particular. This chapter contains an empirical and theoretical review.

The empirical literature review in this chapter examines studies that have investigated interest in energy, with a focus on preferences for renewable energy and solar. Given the focus of RQ1, "*What are the user preferences for solar PV as a form of backup electricity in a Nigerian residential setting?*" on the preferences for solar PV as a form of backup electricity in a Nigerian residential setting, it is necessary to identify the benefits of solar that are valued by residents to properly answer the question. The literature review in this chapter takes a broad approach by first investigating the willingness of respondents to pay for energy broadly. On the basis of the broad understanding of preferences for energy, it goes further to examine the preferences of electricity, specifically backup electricity.

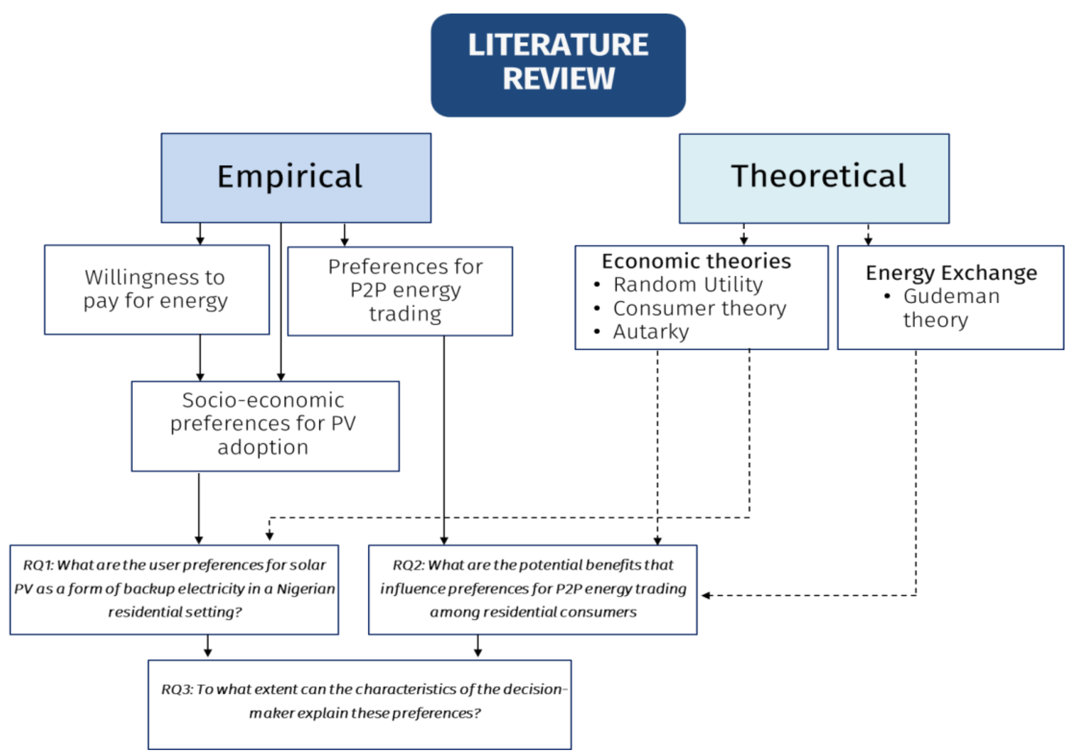
The literature review then focuses on preferences for renewables o gain further clarity on the nature of the existing literature on preferences for renewables, given that solar energy is a key renewable energy resource with applications to the residential electricity sector. The literature review then goes deeper to identify the nature of evidence concerning socioeconomic preferences for solar PV, from environmental, financial, and social viewpoints, amongst others.

This approach to the literature review is also adopted concerning P2P, given the focus of RQ2, "*What are the potential benefits that influence preferences for P2P energy trading among residential consumers?".* Therefore the literature is further examined to identify potential benefits that influence preferences for P2P energy trading among residential consumers, focusing on the benefits that might hold within the research setting. From this review, energy independence aspirations and financial benefits emerge as two broad areas explored in detail in Chapter 6.

The literature review also examines the nature of individual characteristics on preferences in line with RQ3, *“To what extent can the characteristics of the decision-maker explain these preferences?”.* The justification for this research question stems from the literature review showcasing a need to further understand the role of individual characteristics and the effect this has on preferences for solar PV and P2P energy trading. A deeper understanding of individual characteristics can inform the development of updated strategies.

The review examines the key theoretical frameworks applied in the study, primarily the random utility theory, consumer theory, autarky and Gudeman theory of energy exchange. The strengths and shortcomings of the literature are also discussed in this chapter. The chapter concludes by showcasing the research gaps filled by this study. A conceptual framework to guide the literature review in this chapter is presented in Figure 2-1.

Figure 2-1: Conceptual framework for literature review



2.1. Empirical studies on interest in energy

2.1.1. Willingness to pay for energy

The literature review section maps different studies that have investigated preferences for RE. It relies primarily on studies examining the WTP concept related to RE. The concept of WTP measures how much consumers indicate that they are prepared to pay to receive a supply of a specific good or level of service (Hensher, Shore and Train, 2014). WTP studies can give evidence to support decisions made by energy stakeholders such as policymakers or regulators by revealing the value consumers place on various attributes of a particular service (Hensher, Shore and Train, 2014). In the energy literature, WTP analysis has been used to value energy-related goods and services such as green electricity (Roe *et al.*, 2001; Bigerna and Polinori, 2014; Guo *et al.*, 2014; Dagher and Harajli, 2015; Herbes *et al.*, 2015; Sundt and Rehdanz, 2015a; Arega and Tadesse, 2017; Andor, Frondel and Sommer, 2018; Yang *et al.*, 2018), bioethanol (Lim, Kim and Yoo, 2017), reliable electricity services (Otegbulu, 2011; Özbafli, 2011), natural gas (Jang, Lee and Yoo, 2014), flexible prosumers (Kubli, Loock and Wüstenhagen, 2018), RE policy (Longo, Markandya and Petrucci, 2008; Herbes *et al.*, 2015; Polis, Dreyer and Jenkins, 2017), decarbonisation (Cheng *et al.*, 2017), RE investment (Ku and Yoo, 2010), and smart meters (Ida, Murakami and Tanaka, 2014).

2.1.1.1. *Preferences for reliable electricity supply*

Some studies have examined the preferences for reliable electricity supply, showing that consumers tend to be willing to pay above-average energy expenditure for higher electricity reliability. Some identified determinants of WTP for reliable electricity include income, education, and the cost of alternative energy sources (Umaru, 2016).

Differences exist between the WTP of households and firms for reliable electricity supply. For example, Ghosh et al. (2017) found that small-scale manufacturing firms in the Indian region around Hyderabad were willing to pay approximately 20 per cent more for an uninterrupted and reliable electricity supply. Another study in Kenya by

Osiolo (2017) found a significant difference in the monthly mean WTP estimates for households (US$6.34) and firms (US$355.92).

Using the Contingent Valuation (CV), Choice Experiment (CE) and Averting Expenditure (AE) methods, Özbafli (2011) also estimated the WTP for improvements in electricity reliability among residents of Northern Cyprus. The study found that households could accommodate a rise in monthly electricity bills ranging from 1.5 per cent -13.5 per cent to prevent the costs associated with electricity outages. In the UK, Morrissey et al. (2018) used a DCE to estimate the welfare cost to households of power outages and found higher heterogeneity in household preferences for shorter power outages. The study also found an inverse relationship between WTP and the length of power outages across various consumer groups. Siyaranamual *et al.* (2020) used a DCE to investigate the willingness of Indonesian consumers to pay for electricity service attributes and found a large share of consumers willing to pay for electricity improvement.

2.1.1.2. *Studies on preferences for Energy in Nigeria*

An earlier study by Adenikinju (2005) did not directly focus on preferences for energy among households but is still worth reviewing. The study highlighted how inadequate electricity supply meant additional and significant costs for firms that had to acquire and use expensive backup generators to mitigate the substantially more significant losses resulting from frequent power outages. The study concluded that frequent outages led to productivity losses in the business sector in Nigeria, which primarily affected smaller companies.

Another study on WTP for electricity in Nigeria by Otegbulu (2011) explored households' WTP for electricity consumption and mitigation expenditure arising from poor electricity infrastructure in Nigeria using the demand side management approach. Utilizing a closed-ended face-to-face survey of 1,040 households in Lagos, the study found that households in Lagos, Nigeria, were willing to pay additional amounts for increased reliability of electricity supply arising from the averting expenditure nature of providing electricity through self-generation. However, the paper did not specify if households still demonstrated averting expenditure tendencies if faced with alternatives to diesel and petrol fired generators, such as using RE generation sources. However, this might have been the case because RE sources of self-generation were not commonplace and very expensive in Nigeria when the study was published.

The willingness of Nigerians to adopt prepayment electricity metering was explored in the work of Oseni (2015), based on a sample of 835 Nigerian households that were not using such meters. The study found that adopting a prepayment meter is significantly affected by current electricity spending, current billing method and the split incentive problem. The results questioned the validity of the widely held belief that low income may be responsible for prepayment metering, as income was not found to be a significant factor in the decision to adopt prepayment metering and the corresponding amount respondents were willing to pay to adopt them.

Oseni (2016) employed a random-effects probit analysis to estimate how an improvement in publicly supplied electricity may reduce backup generation and, by implication, reduce emissions from Nigerian homes. The study found that even though self-generation would significantly reduce if electricity service quality is improved, affluent and educated households will continue to rely on self-generation due to reduced willingness to dispose of generators. The study, which had methodological rigour, contributed to the ongoing policy debate in Nigeria regarding the government banning or encouraging self-generation. However, the study was limited to household preferences for disposing generators as a backup generation source. It did not consider households switching to alternative backup generation sources such as inverters, batteries, or solar home systems. This thesis contributes to this debate by assuming the role of these alternative backup generation sources.

2.1.1.3. *Determinants of preferences for RE*

Commonly identified positive determinants of factors that influence people's preferences for RE technologies and products include factors such as: individual and family income (Zhang and Wu, 2012; Zorić and Hrovatin, 2012; Sardianou and Genoudi, 2013; Stigka, Paravantis and Mihalakakou, 2014), education (Twerefou, 2014; Kim, Park and Lee, 2018), distance to alternative energy markets (Arega and Tadesse, 2017), understanding of potential RE benefits (Paravantis *et al.*, 2018), membership of environmental organizations (Ward *et al.*, 2011), knowledge (Guo *et al.*, 2014; Xie and Zhao, 2018), the role of family and home ownership (Abdullah and Jeanty, 2011; Dagher and Harajli, 2015), and positive attitude towards RE (Guo *et al.*, 2014; Paravantis *et al.*, 2018) amongst others.

In contrast to these findings, Liu et al. (2017) and Garces-Voisenat and Mukherjee (2016) found that income was surprisingly not a driver of WTP. The choice of methods might have explained their divergent results as Liu et al. (2017) used system dynamics and agent-based modelling techniques. The respondents' specific characteristics in the Garces-Voisenat and Mukherjee (2016) sample might explain their divergent results.

Gender is also a positive determinant of WTP for RE (Sardianou and Genoudi, 2013; Garces-Voisenat and Mukherjee, 2016; Osiolo, 2017; Xie and Zhao, 2018). Similarly, gender differences in WTP behaviour have been found in the literature. Both Arega and Tadesse (2017) and Xie and Zhao (2018) conclude that males tend to have a higher WTP than females. Other influencing factors include electricity consumption bills, bid and payment vehicles (Guo *et al.*, 2014), and trust in government institutions (Dagher and Harajli, 2015).

Age has also been identified by authors such as Zorić and Hrovatin (2012), with Sardianou and Genoudi (2013) concluding that middle-aged and highly educated residential consumers are probably more willing to adopt RE. Furthermore, Zorić and Hrovatin (2012) identified environmental awareness as a factor influencing WTP for RE, while Polis et al. (2017) concluded that WTP is affected by public perceptions of potential social, environmental, and economic risks and benefits of developing RE.

2.1.1.4. *Preferences for RE and Climate policy*

The literature has also examined preferences for various RE policy options. In the UK, Longo et al. (2008) concluded, based on a DCE, that consumers in Bath were willing to pay a higher price for electricity to internalize the external costs associated with a

RE policy. The authors concluded that consumers highly valued electricity from RE sources. In contrast, using a DCE administered to households across England, Wales, and Scotland, Scarpa and Willis (2010) found that even though households valued RE, the value was not enough to cover the high upfront costs usually associated with the technologies. In Germany, Andor et al. (2017) also found that despite the support and acceptance of renewable energy technology (RET), households' WTP for green electricity declined between 2013 and 2015 due to higher costs (in the form of higher electricity bills) associated with *Energiewende* - the country's energy transition policy.

In Japan, Yamamoto (2015) examined the use of interpersonal communication in decision-making on adoption and concluded that subsidization is more effective than purchasing PV power under feed-in tariffs in promoting the diffusion of residential PV systems through interpersonal communication. Using a DCE, Sagebiel et al. (2014) found that consumers were more WTP for RE when cooperatives or municipally-owned electricity utilities offered the energy. The study concluded that consumer choice also drives organizational transformation in the electricity market and political initiatives.

In comparing Italy and Czech household preferences towards climate change mitigation options related to residential energy use, Alberini et al. (2018) found that income primarily drives heterogeneity in WTP estimates in both countries. In Italy, Bigerna and Polinori (2014) estimated households' WTP for RE to contribute 26.4 per cent of the national energy mix, according to the European Union climate change policy. They found that conservatively, Italian households were WTP, ranging from €302.3m to €526m, which was between 8.6 per cent and 15.1 per cent of the cost of achieving the national target.[10]

2.1.1.5. *Review Studies on Preferences for RE*

The meta-regression analysis by Ma et al. (2015) found that consumers tend to have significantly higher WTP for electricity generated from solar, wind or generic RE sources (i.e. not a specific source) than hydropower or biomass. The authors also

[10] The target was for Italy to generate 26.4% of its electricity production from RE sources by 2020.

found that WTP determinants such as RE type, socioeconomic profile and energy consumption patterns of consumers explain less variation in WTP estimates than the characteristics of the study design itself. Another meta-regression analysis of the literature on households' WTP for a larger share of RE by Sundt and Rehdanz (2015) in developed economies demonstrated that people are generally willing to pay to switch to energy from renewable sources. The study concluded that the acceptance of RE is strongly dependent on providing people with information about plans, alternatives and the status quo.

The review by Stigka et al. (2014) addressed the public acceptance of RE as a replacement for fossil fuels in electricity production and found WTP for RE to be positively correlated with income, exposure to information about energy issues, environmental awareness, and level of education. The study also found WTP for RE to be negatively correlated with age and size of household. Oerlemans et al. (2016) reviewed 57 studies that employed CV to estimate WTP for electricity generated from RE sources and found that most focused on developed economies. In terms of elicitation techniques, the most frequent WTP elicitation techniques used in the literature were open-ended and dichotomous choice approaches, which tend to produce varying levels of WTP.

2.1.1.6. *Willingness to pay for electricity from RE sources*

Some studies did not investigate a specific RE source; rather, they examined the WTP for RE-based or "green" electricity. These studies have primarily found that consumers tend to demonstrate an interest in paying higher amounts for electricity from RE sources. For example, Guo et al. (2014) employed the CV method and multiple regression analysis to identify WTP for RE among residents of Beijing, China. They found that, on average, residents were willing to pay between US$2.7– US$3.3 for electricity generated from RE each month, whilst Lee and Heo (2016) found that Korean consumers were willing to pay an additional US$3.21 per month for electricity generated with RE. The mean estimates by Arega and Tadesse (2017) for Ethiopian urban and peri-urban households' WTP for green electricity using a CV was even lower at US$0.66 monthly. Employing a DCE in an Italian city, Vecchiato and

Tempesta (2015) found that 86 per cent of respondents indicated that they would be WTP a higher amount to use electricity generated from renewable sources. Zorić and Hrovatin (2012) also concluded that the median amount households were WTP for RE-based electricity was above mandatory charges for electricity in Slovenia.

Abdullah and Jeanty (2011) estimated that rural Kenyan consumers were willing to spend up to 5 per cent of their monthly income on electricity from solar PV sources. The study found that households preferred to pay more for grid electricity services than PV and favoured monthly connection payments over a lump sum amount. A study in Ghana by Twerefou (2014) focused on the WTP of households for improved electricity from renewable sources and found that, on average, Ghanaian households were willing to pay about one and a half times more than their current electricity costs for a renewable-based electricity supply.

H.-J. Kim et al. (2018) examined the willingness of Korean households to pay for implementing the country's official development assistance plan to construct 5MW RE power plants[11] in developing countries annually from 2017 to 2026. The study found high public support for the plan as the expressed WTP amount was higher than the cost required to build the plants. Lienhoop (2018) used a DCE to explore local preferences for various forms of financial and procedural participation in German wind energy projects. The authors found that such projects tend to be accepted by the local public if they were offered conditions such as shareholding and high levels of participation in the decision-making process.

Some studies focusing on WTP for solar energy have found that despite the relatively high WTP for solar PV, consumers will require specific information before deciding to use the systems due to uncertainties and cost constraints. Such information can range from economic to technical details. For example, in Germany, Gährs et al. (2015) used data from 500 face-to-face interviews with private owners of PV systems and found that about 69 per cent of the PV owners were willing to invest in PV-storage-systems. Similarly, Abdullah et al. (2017) explored public acceptance and interest in

[11] Wind, photovoltaic, and biomass power plants

Pakistan's SHS. Using data from a survey, they found interest in SHS high, with about 81 per cent of the study respondents interested in the technology.

The reliability of solar PV systems is also vital to their acceptance by consumers. Graber et al. (2018) used a DCE in 22 villages to investigate differences between consumer preferences for electricity from solar microgrids and the centralized utility grid in India. The authors found that consumers valued reliability and price, among others. The consumers were also more satisfied with the reliability of electricity supplied by solar microgrids despite providing lower hours of electricity than the primary grid.

2.1.2. Socioeconomic Preferences for PV adoption

Previous studies on public attitudes towards solar energy and renewables in the Global North show that in the U.K., people are open to opportunities for further involvement in RE development (Rogers *et al.*, 2008). Carlisle *et al.* (2015) found that there is general public support for the development of large, utility-scale solar power projects in the U.S. Tsantopoulos, Arabatzis and Tampakis (2014) discovered that in Greece, people are well-informed and willing to invest in solar PV systems either at home or on a plot of land. When examining attitudes towards RE, Karlstrøm and Ryghaug (2014) highlight the need to consider political contexts based on evidence from Norway, where it was seen that political leaning had a more significant impact on energy technology attitudes than has been previously thought.

In the Global South, some studies have focused on the socioeconomic impact of solar systems in rural areas in South Asia. For example, Wijayatunga and Attalage (2005) examined the social, economic and environmental impact of solar home systems in rural Sri Lanka and found that in addition to being extremely satisfied with the technology, rural dwellers had improvements in their socioeconomic conditions and better environmental conditions resulting from the use of the solar home systems. Mishra and Behera (2016) found that in two rural Indian villages, solar power has improved socioeconomic activities and the standard of living of households, most especially that of women in rural areas. They also found that active participation of local actors and community-level organization would go a long way to enhance households' inclination towards increased use of solar energy. A review of the literature on the impacts of SHS and solar home lanterns in rural areas by Lemaire (2018) showed that these systems could significantly impact the quality of life of end-users. The impact channels include connectivity via mobile phones and television sets, an increase in lighting quality, costs savings from replacing kerosene lamps with solar lighting, and solar lighting benefiting children's study time and quality of education.

Within the African context, Howells et al. (2005) modelled household energy services in a low-income rural village in South Africa, factoring in the social and environmental costs of energy use. They found that factors other than economic factors affect the household energy use pattern. Ulsrud et al. (2015) analysed a solar power model developed and tested using action research in a local Kenyan village. Their analysis established that an energy center model can cover basic electricity needs in many places in Africa with dispersed settlement patterns where mini-grids and traditional grid extension might not be feasible. They show that committed follow-up of local actors and a flexible socio-technical design that allows for improvements after implementation would go a long way in enhancing village-level solar projects' economic sustainability and smooth functioning.

Earlier studies on solar energy in Nigeria focused on assessing the viability of solar PV for energy generation in the country. Previous studies on preferences for solar energy in Nigeria have also focused on rural consumers with little evidence of preferences of residential consumers in estate settings. For example, Adeoti, Oyewole and Adegboyega (2001) estimated that villages in Nigeria without access to the grid would require 597.5kWh/year, whilst those with access to the grid would require 850.8kWh/year to meet the basic power requirements for needs such as lighting and to electric power appliances. Oparaku (2002) also surveyed and examined the status of solar PV in two villages in Nigeria and found that some of the installations failed due to inadequate design. The study also found that solar PV power systems have enhanced living standards in rural communities. The study also showed that solar power systems are predominantly used for water pumping in rural Nigerian villages.

Using sensitivity analysis, Oparaku (2003) compared the costs of solar PV systems, diesel/gasoline generators and the electric grid and found that solar PV is the most cost-effective solution for low-power rural energy supply in Nigeria.

In a seminal study, Ugulu (2016) investigated adoption barriers and motives for solar energy in Nigeria. Employing correlation and logistic regression analysis, the study found high capital costs, lack of finance and low awareness to be significant barriers to adoption. In contrast, field survey analysis revealed power outages and cost-savings, including generator fuel theft and access to finance, as the key motives for the uptake of solar PV in Nigeria. The study also found that energy-efficient practices were prevalent among PV-adopting households. From a policy perspective, the study also demonstrated the role of government incentives in influencing the large-scale uptake and diffusion of solar PV in Nigeria. Despite the focus of this study on the WTP of urban households for solar PV, the study did not consider WTP and preferences for specific attributes of solar energy and how these attributes might influence uptake.

Another study by Elegbede *et al.* (2021) used a DCE to assess the trade-offs associated with utilising off-grid solar chargers from the perspective of rural Nigerian households and found that confidence in product quality was the most important factor and that respondents associated higher-priced solar chargers with higher quality. Nduka (2021) found that rural households have strong preferences for RE, based on a study that used the CV to elicit responses and estimate the WTP for a pico-PV system and improved cookstoves (ICS). Babajide and Brito (2021) found cost savings of up to 65 per cent over the project life from using SHS compared with diesel generators for backup power generation in Lagos, Nigeria, based on evidence from financial analysis. Using the CV method and a survey of 400 participants in Ibadan, Ayodele *et al*. (2021) found that respondents were willing to pay, on average 5 to 10 per cent above their present electricity costs. The key factors influencing WTP in the study included income, age, marital status and education level. Adeleke *et al.* (2022) examined households' poverty status and willingness to pay for RE in Southwestern Nigeria and found that age, marital status, level of education, household size, house location, income and awareness about RE are factors influencing surveyed households' WTP and payout levels for RE. (Nduka, 2022) analyzed Nigerian households' WTP for solar PV under various scenarios and found that WTP for solar PV is higher when it can displace generators completely. The study also concludes that the use of a payment mechanism involving a subsidy and a monthly payment rather than an upfront payment would scale up the adoption of solar PV by about 6 per cent.

2.1.2.1. *Environmental Benefits of Solar PV*

Consumers see electricity generated from clean energy sources in multiple ways: as an environmental benefit, a consumer good, an innovative technology, and marketing efforts aimed at environmentally concerned individuals may need to emphasize non-environmental benefits, as Wolske *et al.* (2017) pointed out. Similarly, Bergek and Mignon (2017) argued that there are different motives for adopting RE technologies, including environmental benefits; however, there are differences in the magnitude of importance attached to each motive. Conversely, Schelly (2014) found that environmental values were not enough and necessary to motivate adoption.

2.1.2.2. *Financial Benefits and Costs*

Financial incentives are essential determinants in the decision-making process to adopt solar systems (Simpson and Clifton, 2017). A systematic literature review by Palm (2020) on the factors that motivate people to adopt solar photovoltaics (PV) found that early adopters are driven mainly by concerns for the environment and technological interests, while later adopters are primarily motivated by financial benefits. Bondio *et al.* (2018) suggested that the adoption of PV by households could be optimum when they are faced with rising electricity bills and have sufficient capital to afford the upfront cost. According to Vasseur and Kemp (2015), the adoption of Solar PV in the Netherlands depends on the perceptions of its attributes; and, more importantly, the cost. In a household survey, Zander et al. (2019) found that installation costs, returns on sales of excess solar power, and a high feed-in tariff influenced the choice of a photovoltaic system. It was further revealed that knowledge about RE policies and beliefs in the environmental benefits of solar energy positively influenced the willingness to install a photovoltaic system; the latter was also applicable to Income and education, while age had a negative effect.

Results from a survey on solar PV adoption in the US indicated that cost savings, solar system reliability, installer warranty, and reviewer ratings of the installer were the most important factors when homeowners considered purchasing a solar system. There were also differences between adopters and non-adopters with respect to location, age, and income (Bao *et al.*, 2020). Islam (2014) found that technology awareness and energy cost savings significantly predict adoption probability. In the same vein, return on investment and social and other non-economic drivers influenced the financial motives of members of smaller communities (Bauwens, 2019). Furthermore, the aesthetic properties of solar panels could influence adoption and increase the customer base (Petrovich *et al.*, (2019).

2.1.2.3. ***Social Factors***

Social factors in the form of peer effects have also been found to affect the adoption of solar PV at the household level. These effects are related to the influence of peers such as neighbours, friends, relatives or colleagues on a person's behaviour (Georgarakis *et al.*, 2021). These peer effects can facilitate the diffusion of solar PV by reducing barriers to adoption and increasing trust in the technology (Palm, 2017) and fostering investments (Bauwens, 2019). For example, adopters are more likely to have friends, relatives, and neighbours who have already installed solar panels than non-adopters (Petrovich *et al.,* 2019). Similarly, Bollinger and Gillingham (2012) found that Californian homeowners in a given zip code were 0.78 percentage points more likely to adopt solar photovoltaic for every additional installation in the zip code.

Another strand of the literature on peer effects outlines interest in consuming RE generated from cooperatives. For example, Rommel *et al.* (2016) found that consumers are willing to pay approximately double for RE offerings by cooperatives or municipally-owned electricity utilities compared to investor-owned firms. Opinion leaders have also been crucial in diffusion as they influence opinions on innovations and can provide vital information on technical or financial performance investments (Bauwens, 2019). Yamamoto (2015) found a positive relationship between opinion leadership and solar PV adoption in Japan. Drawing on fifty-five semi-structured interviews in an Australian case study, Simpson (2017) found that social interactions within communities motivated solar adoption in addition to financial incentives. The study also highlighted the role of a local "solar champion" in fostering adoption within communities.

2.1.2.4. *Other Factors*

Political affiliations and preferences for solar energy have been investigated in the literature. Palm (2020) found a declining relationship between Green Party voting and solar PV adoption based on data from Swedish consumers and concluded that earliest adopters are more driven by non-financial motives such as environmental concerns than later adopters. Briguglio and Formosa (2017) also found that pro-government sentiments positively influenced the take-up of grants and installation of PV panels. Individual perception of government policies can also affect social acceptance of RE. Simpson (2017) found that government policies toward RE were deemed unreliable and retrogressive by different consumers in Western Australia.

The provision of accessible information and emphasis on household self-sufficiency in energy is also vital to the uptake of solar-based microgeneration technologies (Balcombe *et al.*, 2014). Similarly, installers and neighbours play important supplementary roles in households' solar PV adoption decision-making process and influence the decision to adopt and the adoption mode (Rai *et al.*, 2016). In terms of business models, Rai and Sigrin (2013) found that the leasing model more effectively addresses consumers' informational requirements and has a market with a potentially sizeable residential audience in a "tight" cash-flow situation.

2.1.3. Gaps in solar energy preferences literature

The studies examined have analysed various aspects of solar energy technology, such as the attitude of the public towards solar energy, the socioeconomic impact of solar systems in rural areas, and the long-term viability of solar systems. Many of these studies on off-grid solar power have also examined it from a top-down perspective and an economic and technical perspective. However, there is little emphasis in the literature on the adoption of solar PV for backup electricity adoption among end-users, especially in contexts with erratic grid supply.

The literature also shows gaps in assessing the importance of flexible, decentralised payments in attracting reliable low-income customers to use distributed RE solutions (Moreno and Bareisaite, 2015). Potential investors also need to know customers who would be willing to adopt renewable technology, which would lead to revenue generation (The Economist, 2017)

There are also critical knowledge gaps on productive uses and local value chains of mini-grids, private operators' business models, rationales, incentives, field issues or potential revenue streams (Contejean and Verin, 2017). A study by Grimm *et al.* (2017) concludes by highlighting the need for further studies that can examine the mechanisms behind take-up behaviour, such as the households' WTP for electric energy, the role of credit constraints, and information.

This study contributes to the literature by examining off-grid solar energy from a bottom-up approach, focusing on the end user's perspective. It also looks at end-users' preferences regarding solar PV in Nigeria as a form of backup electricity from a social science perspective.

2.2. Consumer preferences for participating in P2P energy trading

This sub-section examines the literature on P2P energy trading focused on consumer preferences for participating in trading. From the user perspective, Morstyn *et al*. (2018) noted three value propositions for P2P energy trading of renewable energy. These are energy matching, preference satisfaction, and uncertainty reduction. The first, energy matching, refers to how P2P energy trading platforms can serve as a market mechanism that incorporates prosumers' individual preferences and the specific characteristics of electricity. P2P trading platforms do this by "allowing mutually beneficial energy transactions to be negotiated between prosumers with excess energy and those with complementary demands" (p. 96). Preference satisfaction refers to P2P energy trading's capability to allow prosumers to determine and track preferences on energy sourcing and for energy to be traded according to these preferences. Finally, uncertainty reduction deals with the incentives for investments in renewable energy that result from trading energy within a local P2P market, which increases revenues for prosumers and reduces the uncertainty associated with investments in distributed energy resources.

Whilst limited, empirical evidence from surveys with prospective prosumers has been used to depict preferences for P2P energy trading. For example, using survey data from a sample of 301 German homeowners, Hahnel *et al*. (2020) analysed hypothetical P2P energy trading decisions. They found the determinants of homeowners' trading behaviour to include community electricity prices and state of charge of private energy storage. The study also found heterogeneity in preferences and identified four target groups that systematically differed in their decision-making strategies, ranging from price-focused prosumers to classic non-trading consumers. Similarly, Hackbarth and Löbbe (2020) surveyed customers of seven German municipal utilities and found that households were open to participating in P2P energy trading. Individuals' environmental attitudes, technical interests, and independence aspirations were essential motivating factors. The authors also found that a high willingness to participate in P2P energy trading was motivated by the ability to share electricity, and to a lesser extent, by economic reasons. Innovative pricing schemes are another aspect of P2P energy trading that can influence users' willingness to participate (ibid.). People planning to install microgeneration technologies were also considered the most promising target group for P2P energy trading in the study.

Furthermore, Ableitner *et al.* (2020) used data from 35 households and two firms in Switzerland's first real-world P2P energy market to investigate the user behaviour of families and their future role in decentralised energy scenarios. The study applied a mixed-method approach and found that P2P energy trading was well-received among respondents with heterogeneous preferences. The study also classified respondents into three groups based on their pricing preferences: consumers who want to set prices actively, those who prefer automated prices determined by an information system, and non-users. Interviews from the study also revealed that P2P energy trading markets can likely increase the prominence of renewables and may promote load-shifting activities. Furthermore, Georgarakis *et al.* (2021) found that regarding P2P energy trading, prosumers mostly valued environmental and, to a lesser extent, economic dimensions in the Netherlands.

A set of case studies by Sorin *et al*. (2019) showed that P2P market structures could effectively yield different market outcomes from centralised market structures and optimize consumer preferences while maximising social welfare. Based on a survey conducted in four countries (Switzerland, Norway, Spain and Germany), Reuter and Loock (2017) argued for the need to adjust product and service offerings in local electricity markets to properly reflect the needs of existing and prospective consumers and prosumers. Liu *et al.* (2019) analysed the effectiveness of auctions and bilateral contract-based P2P energy trading mechanisms in managing energy trading among prosumers in future electricity distribution systems.

There have been minimal studies on P2P energy trading in Nigeria. Oyekola (2020) modelled and simulated a decentralized distributed solar photovoltaic generation network in the Lagos State of Nigeria that adopts blockchain technology as the energy-trading platform. The study demonstrated that implementing a decentralized distributed solar photovoltaic generation network into the Nigeria energy system could improve energy generation and supply reliability and efficiency during different seasons of the year. Okwuibe (2019) developed a P2P trading platform for trading excess RE on an Ethereum blockchain at the microgrid level in Nigeria. The most beneficial prosumer-to-consumer combination was to have a ratio of one prosumer to three consumers. However, a shortcoming of this study is that it relied on simulated PV data from Germany, which is not necessarily applicable to Nigeria, given the differences in solar radiation between the two countries.

2.2.1. Gaps in P2P energy trading literature

In the literature, several review papers have summarised the state of evidence on P2P energy trading and energy prosumers, covering technical, socioeconomic, policy and regulatory aspects of P2P energy trading (see, for example, Tushar *et al.* (2018); Soto *et al.*, (2020) and Wang *et al.* (2020) among others). As Dai *et al*. (2020) identified, studies have emphasised the theoretical, application, policy, and modelling aspects of P2P energy trading. The literature has also captured other essential elements of P2P energy trading, such as market design, the nature of trading platforms, physical and ICT infrastructure, and social science perspectives (see Mengelkamp *et al.*, (2018); Sousa *et al.* (2019); Zhou *et al.* (2020)). Within this broad range of topics, Zhou *et al.* (2020) found that most P2P studies have focused on market design, with a sharp increase in published papers between 2018 and 2019. Several authors have also outlined challenges for the scale-up of P2P energy trading, given the limited implementation of the model in electricity markets. These challenges include integrating generation, transmission, and distribution aspects, the need for large-scale studies, and modelling complex consumer and prosumer behaviour (Soto *et al.*, (2020); Tushar *et al.* (2020) and Tushar, Saha, Yuen, Smith, *et al.*, (2020)).

In terms of market mechanisms for the integration of prosumers, Parag and Sovacool (2016) identified three potential prosumer markets related to prosumer grid integration, P2P models, and prosumer community groups. Similarly, Morstyn and McCulloch (2020) presented an overview of different business models that P2P energy trading can support and used case studies to demonstrate that P2P energy trading platforms with a combination of solar energy generation sources, home battery systems, and electric vehicles are of value to prosumers. The review by Wang *et al.* (2020) found an emphasis in the literature on operational models and local markets, with little focus on wholesale market integration and investment models. The study found that bilateral contracts were the most common in the literature regarding trading mechanisms. At the same time, Sousa *et al.* (2019) concluded that the hybrid P2P market design is the most suitable in terms of scalability, giving room for all other P2P designs to interact. The authors also concluded that there are conditions to deploy P2P markets in co-existence with existing market structures; however, potential conflicts with historical actors need to be avoided to enable a smooth and manageable transition toward P2P markets.

Given the lack of many real-world applications, studies have often employed game-theoretic approaches to simulate the feasibility of P2P energy trading. The review by Tushar *et al.* (2018) thus found that studies have used game-theoretic methods (cooperative and non-cooperative games) in three smart energy domains, notably electric vehicles (EV), distributed energy resources, and service domains. Some review studies have also focused specifically on certain countries and regions, while some studies focused on the regulatory challenges surrounding P2P energy trading. For example, Kokchang *et al*. (2020) found that the main regulatory barriers limiting P2P energy trading in most countries are issues with licensed energy suppliers, network charging, and restrictions on feeding excess generation back to the central power grid. Alongside an enabling regulatory framework and evolving customer preferences, Löbbe and Hackbarth (2017) concluded that digitalisation provides an opportunity to reach previously unprofitable customer segments. The study also concluded that technology like blockchain could improve the efficiency of distributed energy systems based on evidence from Germany.

2.3. Theoretical Review

This research engages a mix of theoretical concepts to meet its objectives. These include the Random Utility theory, Consumer Theory, Gudeman’s Theory of Mutual Energy Exchanges and Autarky theory, as summarized below.

2.3.1. Random Utility Theory

This study employs a Discrete Choice Experiment approach (described further in Section 3.5), which is based on the Characteristics Theory of Demand (CTD) (Lancaster, 1966) and the Random Utility Theory (RUT) (McFadden, 1974; Manski, 1977). The CTD assumes that goods, services, or in this case dwelling in a home with clean and quiet benefits can be valued in terms of their constituent characteristics (otherwise known as attributes). The RUT assumes that respondents maximise utility by making a choice based on the levels of attributes (in DCE scenarios) and this utility can be broken down into a systematic component and a random component (Ghijben, Lancsar and Zavarsek, 2014). The systematic component is assumed to be a function of attributes and their levels, while the random component is assumed to be analogous to an error term in a regression equation related to unmeasured preference variation. Hence based on data from the SP of respondents, econometric methods can be used to analyse consumer preferences. The RUT assumes that individuals will always choose the alternative with the highest utility. For example, a household faced with the choice between a house with backup generators or one with solar PV system will go for the one that gives them the most utility. Following Wittink (2011), this utility is treated as a random variable as the utility of a decision maker is not known with full certainty, and the probability that a decision maker will select a certain alternative is

$$P(i|C_n) = \Pr(U_{in} \geq U_{jn}, \forall_j \in C_n) \quad \ldots (1)$$

- Where U_{in} is the unobserved utility that an individual n derives from an alternative i
- If the choice set C_n has only two alternatives i and j, then we have a binary choice model
- If the choice set C_n has alternatives ranging from i to j, then we have a discrete choice model.

Therefore, the probability that the individual n will make a choice between the alternatives is:

$P_n(i) = \Pr(U_{in} \geq U_{jn})$ and $P_n(j) = 1 - P_n(i)$ … (2

2.3.2. Consumer Theory

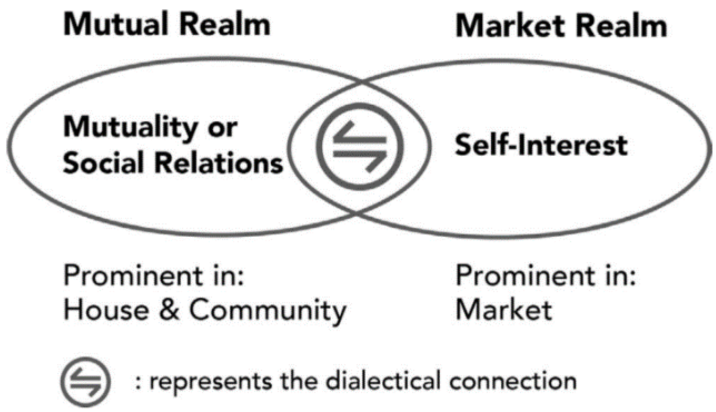
Another theory which lends credence to this study is Consumer Theory. The basic hypothesis of consumer theory is that individuals will always choose a most preferred bundle of goods from a set of affordable alternatives (Varian, 1992). The theory assumes that each consumer has a stable preference system that can be described by a utility function. Thus, the consumer optimization problem is to choose the combination of goods and services that will maximize their satisfaction, given their budget constraint. The solution to this problem is the consumer's demand function, which represents the optimal quantities of each good and service that the consumer will demand, given their income and the prices of the goods and services.

Several key assumptions are often made in consumer theory, including the assumptions that consumers are rational and aim to maximize their satisfaction, have well-defined preferences, have complete information about the prices and characteristics of the goods and services available to them, have a stable set of preferences, and have a fixed budget constraint. The consumer's budget constraint represents the limitations on their consumption due to their income and the prices of the goods and services.

2.3.3. Gudeman's Theory of Mutual Energy Exchanges

Economic anthropologist, Stephen Gudeman in his books, (Gudeman, 2001, 2008, 2016) uses evidence from various ethnographic studies he conducted in developing countries in Latin America and Africa, to argue that an economy consists of two dialectically connected realms, the community/mutual realm and the market realm (Gudeman, 2001 pp.1; 2008 pp.4). The community/mutual realm refers to "real, on-the-ground associations and to the imagined solidarities that people experience" while the market realm designates anonymous short-term exchanges which are impersonal, global and abstracted from social context; consisting of separated but interacting agents. He argues that the relationship between the two dimensions is complex, as sometimes they are separated, while other times they are mutually dependent, opposed or interactive. He further explains that economic practices and relationships are not only constituted of the two realms, but also consist of four value domains; the base, social relationships, trade and accumulation. Gudeman further argues that there are two dialectically connected realms of exchange; the market realm of trading and the mutual realm of sharing as seen in the Figure 2-2 below.

Figure 2-2: Dialectic in the two realms of an economy.



Source: Adapted from Singh *et al.* (2017)

The significance of mutuality differentiates sharing from trading. Sharing creates mutuality and is a process of 'making and maintaining community'. Gudeman (2016) explains differences between social relationships in the market and mutual realm as 'the market realm revolves about short-term material relationships that are undertaken for the sake of achieving a project or securing a good[12]. In the mutual or communal realm, material goods are exchanged through relationships which are kept for their own sake. The material life in the mutual realm is established and sustained through enduring social relationships

Gudeman critiques the strictly market-based view of neoclassical economics which limits market exchange to bounded exchange, that is exchange constrained to a certain range[13]. He argues that such conceptualization overlooks non-market exchange such as sharing. Furthermore, Gudeman argues that the mutual realm is built on social values that differ from anonymous exchange. Gudeman argues that in a market, people exchange goods, buying and selling at the best price available. Until they are satisfied, they cannot better their personal holdings. Exchanges in community are different, as they revolve about ways of dividing a shared base, are guided by multiple values, and have to do with fashioning identities as well as material life.

[12] For example, the sales representative for a car dealership that becomes his "friend" for a period only to disappear after completing the sale

[13] For example, a government-issued food stamps that can be traded only for a range of foods.

Gudeman’s theory argues that in the mutual realm, or the mutual transaction realm, the paramount value domains are the base and social relationships, while in the market realm, the paramount value domains are accumulation and trade.

An application of this theory in this thesis involved investigating whether residential consumers of solar energy in Nigeria place more emphasis on carrying out energy exchange aimed at fostering independence from the grid, or energy exchange to achieve both material and end gains. This would help us understand more about the role in which energy exchange can play in building and maintaining community as well as material or financial gain. To carry out this research in practical terms, the survey of estate residents included a section that captured interest in trading energy via a community-based platform. Specifically, it examined possible reasons why these residents would be interested in energy trading such as the ability to share the burden of generating electricity with neighbours and financial benefits such as earning additional income.

2.3.4. Energy Autarky or Independence Aspirations

Autarky, which finds its roots in the economics of international trade, refers to a country that operates in a state of self-reliance or self-sufficiency and limited trade with other countries. According to the Merriam-Webster dictionary, the term *autarky* is derived from the Greek word *autarkes* and means “economic independence or self-sufficiency” (Merriam-Webster Dictionary, 2022). A fully autarkic nation would be a closed economy and lacking any sources of external support, trade or aid (Kenton, 2021). Energy independence has been distinguished in the literature as autarky (self-sufficiency or independence of energy supply) and autonomy, with autarky conceptualised as the goal of energy independence. In contrast, autonomy deals with how the goal is achieved, such as the ability to self-determine one's energy provision (Adams et al., 2021).

Previous studies on decentralized sustainable energy systems showed the importance of autarky considerations. For example. Korcaj, Hahnel and Spada (2015) found that autarky aspirations strongly predict homeowners’ attitude toward solar PV systems, affecting homeowners' purchase intentions. The authors further concluded that the desire to generate energy in an independent, self-determinant, and self-sufficient way was crucial in achieving acceptance and commitment. Engelken *et al.* (2018) found perceived autarky and financial benefits to be the most relevant attitudinal predictors of private households' intentions to purchase renewable energy system components with the purpose of partial energy self-supply in Germany. In addition to ownership and control, autarky was found to be a key product attribute valued by consumers for new battery storage business models in Germany (Kalkbrenner, 2019). Hahnel *et al.* (2020) also find that *autarky-focused* prosumers are willing to invest in community energy storage systems that increase the community's independence from external stakeholders such as classic energy providers.

As with other studies, including Ecker, Hahnel and Spada (2017); Ecker, Spada and Hahnel (2018); Schmidt et al. (2012), this study draws on the conceptual framing of energy autarky by Müller et al. (2011). The authors conceptualize energy autarky as a situation in which the energy services used to sustain local consumption, production and exchange of goods and services are based on local RE resources. There are several potential benefits of autarky in the energy sector for individuals including independence, enhanced energy efficiency, environmental benefits as they limit autarky to the use of clean energy source, and resilience. Although Müller et al. (2011) conceptualise energy autarky in a regional context, this thesis extends it to the residential estate level by considering the independence of energy supply for individuals dwelling in residential estates.

2.4. Discussion

First, the literature is rich in identifying determinants of WTP and studies in different contexts have examined this in detail. The literature also agrees that differences in WTP estimates and market acceptance for various RE sources are primarily positive and context-specific. Thirdly, there is comprehensive coverage regarding energy sources as the literature is rich in investigating WTP for electricity generated from various renewable sources. Some studies focus broadly on renewable-based electricity, while others focus on power from individual sources like wind and solar. There's also some agreement in the literature that consumers are interested in paying (sometimes higher costs) for reliable supply from renewables.

An identified gap in the literature is using qualitative research in attribute selection for SP studies in energy**.** When deciding on attributes to include in a choice experiment, authors can use approaches ranging from purely theoretical to qualitative. For the qualitative approaches, studies have often either carried out exploratory interviews or focus group discussions with the population of interest on deciding on the attributes to include in the study. These interviews can also be used to understand the language such participants use, which can prove valuable to ensure the respondents can understand the language used in the DCE.

Studies in health economics using DCE have incorporated this qualitative process in determining the attributes to include. However, the literature on WTP using DCE in energy appeared to place less emphasis on the qualitative process. Only recently, a handful of studies in the energy literature have been identified to incorporate qualitative studies such as focus group discussions (for example, Oseni, 2015, 2016; Lienhoop, 2018) and interviews (Glumac and Wissink, 2018). However, these studies have little evidence on the methodological approach in the qualitative phase, providing scant details on the sampling and analysis conducted to select the attributes.

Furthermore, in presenting an agenda for energy and social science research, Sovacool (2014) raised an important point by challenging researchers to investigate "how best the benefits of 'human-centred' research methods can be coupled with quantitative forms of data collection and analysis.". The inclusion of qualitative methods in DCE studies has been recommended as a good practice in the health economics literature (Coast and Horrocks, 2007; Bridges *et al.*, 2011; Johnson *et al.*, 2013; Johnston *et al.*, 2017) and has been recommended for adoption in environmental and energy studies (Rakotonarivo, Schaafsma and Hockley, 2016). Thus, this study follows suit by embedding a qualitative process in the development of the DCE.

Oerlemans et al. (2016) highlighted that most of the WTP studies using the CV method have been on developed countries, with few studies on developing countries such as those in Africa. With the rising population, urgent energy access needs, and the importance of providing energy through RE to mitigate climate change, it is pertinent to have more studies in this area conducted on developing African countries to inform policy and practice in these countries. As the study by Grimm et al. (2017) concluded, there’s a need for further experimental studies that can examine the mechanisms behind the take-up behaviour of SHS in developing countries, including households’ WTP for electric energy, the role of credit constraints, and information.

On P2P energy trading, the literature review shows that this is a topic that has garnered interest in recent years, given its potential to transform the way energy is produced, distributed, and consumed. The literature on P2P energy trading has identified a number of potential benefits, including increased efficiency and reliability of the electricity grid, reduced costs for consumers, and increased adoption of renewable energy. The literature has also identified a number of challenges that need to be addressed for P2P energy trading to succeed, including technical and regulatory barriers, as well as issues related to fairness and equity.

However, the literature review shows that there is growing, albeit limited, literature on the preferences of individuals to engage in P2P energy trading. All the identified consumer survey studies were based on developed countries, with little evidence on developing countries. Similarly, no studies on consumers' preferences in the global south or Africa have examined household or individual preferences for P2P energy trading. This study also finds limited evidence in the literature on the differences in personal preferences for energy trading regarding buying and selling energy with neighbours within a residential estate setting.

This study aims to contribute to the literature by filling this gap. Furthermore, this study also contributes to the literature by investigating consumer preferences for energy trading within contexts with grid supply and the role of autarky aspirations in addressing individuals' preferences for a reliable electricity supply in such contexts.

2.5. Conclusion

In summary, this section review has focused on the literature on WTP for RE and preferences for P2P energy trading. It has highlighted some of the key findings and strengths of the literature, including identifying determinants of WTP and highlighting context-specific differences in WTP estimates and market acceptance for various RE sources. Furthermore, the literature is also rich in investigating WTP for electricity generated from multiple renewable sources.

This review has also identified some research gaps, including the need to approach RE adoption from the perspective of the benefits to the local environment of users and not just the global benefits in the form of environmental and climate change mitigation. It also highlighted the need for more DCE studies in the RE field that embed a thorough qualitative process in attribute selection. This review found a relatively small number of studies on developing countries and WTP for solar as a form of backup electricity and the WTP for specific attributes of solar PV. Finally, there is also a gap in studies on consumer preferences for energy trading.

3. CHAPTER 3: RESEARCH DESIGN AND METHODS

Chapter Overview

This chapter discusses the mixed methods research design adopted in this study to answer the research questions and achieve the objectives. The pragmatic research paradigm employed in this study is discussed. This chapter also provides a detailed explanation of the qualitative and quantitative methods employed, including data collection. It discusses the main phases of the analysis, including thematic analysis used in the qualitative phase and discrete choice modelling of preferences employed in the quantitative phase. Structurally, after the introductory section of this chapter which outlines the overarching mixed-method research design and paradigm, this chapter is further sub-divided into two parts. Part I focuses on the qualitative research method, while Part II focuses on the quantitative research methods employed.

3.1. Introduction

Research design is a critical step in carrying out a scientifically robust study as it helps to reduce measurement errors and enhance the strength of the results (Black, 1999; Maxim, 1999; Yin, 2008). It provides a blueprint for research by addressing four issues: what questions to study, what data is relevant, what data to collect, and how to analyse the results. This chapter discusses the mixed methods research design adopted in this study to answer the research questions and achieve the objectives. This chapter also explains the research methods employed and discusses the main phases of the analysis conducted.

3.2. Research paradigm

The type of beliefs, worldview, or paradigm of the researcher(s) conducting a study can influence the approach used (Creswell, 2014). Hence it is essential to acknowledge and expressly state this. It is also necessary to communicate the philosophical and theoretical position employed in a study. There are broadly four research paradigms (Postpositivism, Transformative, Constructivism, Pragmatism) identified by Creswell (2014).

This research is driven by a desire to understand how adopting solar PV, and P2P energy trading can address challenges associated with grid provided electricity supply and fossil-fuel-based backup generators in Nigeria. This problem centred focus is closely aligned with the core view of pragmatism, which is that pragmatism is an attempt to gain knowledge in pursuit of desired ends and not just the abstract pursuit of knowledge through inquiry (Morgan, 2007).

Pragmatism considers the research question to be more important than either the method or the world view that underlies the method (Tashakkori and Teddlie, 2010). Pragmatism is not just a recent view, as it existed before quantitative and qualitative methods. Creswell (2014), citing Murphy (1990), noted that pragmatism as a paradigm arose from the works of writers such as Peirce, James, Mead, and Dewey. While this philosophy has evolved into different forms, as a worldview, it emerges out of actions, situations and consequences, as opposed to antecedent conditions in the case of other worldviews such as post-positivism. Rather than focusing on methods, pragmatism emphasises solving the problem and what works, hence all available approaches to understanding the problem are employed (Rossman and Wilson, 1985; Patton, 1990).

Proponents of mixed-method approaches such as Rossman and Wilson (1985); Onwuegbuzie and Johnson (2004); Morgan (2007); Tashakkori and Teddlie (2010) have argued that combining insights from qualitative and quantitative data can provide a rich and insightful analysis of complex phenomena beyond what can be achieved by using either one in isolation. As a philosophical underpinning for mixed methods studies, authors such as Patton (1990); Morgan (2007); Tashakkori and Teddlie (2010) emphasize that pragmatism has an essential role in focusing attention on the research problem in social science research and then using pluralistic approaches to derive knowledge about the issue (Cresswell 2014).

Hence, this study followed a pragmatic approach in formulating the research questions and design. However, pragmatic approaches are not without challenges, including the tendency to build on fewer foundations than more established research traditions. They may also not have thoroughly defined research protocols; hence research employing pragmatic approaches requires understanding different theoretical positions and using a wide range of methods to collect and analyse data (Morgenstern, 2016). This can serve as a threat to the quality of the research conducted. To mitigate against this, a detailed process was followed to ensure the quality of the data gathered and the interpretation at all phases of the research.

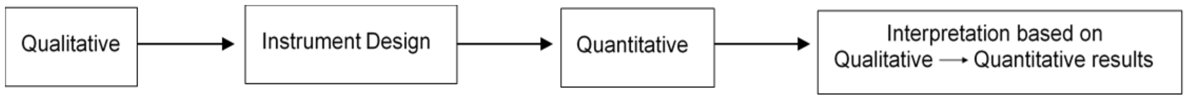
3.3. Mixed Methods Research Design

Mixed methods research collects qualitative and quantitative data in one study and integrates these data at some stage of the research process (Halcomb and Hickman, 2015). Creswell (2014) describes mixed methods research as an approach to an inquiry involving collecting quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may include philosophical assumptions and theoretical frameworks. The central premise here is that combining qualitative and quantitative approaches provides a better understanding of a research problem than either approach alone (Östlund *et al.*, 2011). Qualitative data tends to be open-ended without predetermined responses, while quantitative data usually includes closed-ended responses found on questionnaires or psychological instruments (Creswell, 2014).

3.3.1. Exploratory Sequential Mixed Methods

Exploratory Sequential Mixed Methods (ESMM) is a Mixed Methods approach whereby the researcher initially carries out a qualitative research phase and explores participants' views (see Figure 3-1). The data is analysed and informs the subsequent quantitative phase. The qualitative phase may be used to build an instrument that best fits the sample being studied, identify appropriate instruments to use in the quantitative phase, or specify variables used in the follow-up quantitative study. One of the strengths of the ESMM is that the different stages make it relatively easier to gather, analyse and report findings from data. Challenges to this design include focusing on the relevant qualitative results and the sample selection for both phases of research. (Creswell, 2014).

Figure 3-1: Exploratory Sequential Mixed Method Research Design employed in this study



The mixed methods and specifically ESMM research design is chosen due to the strengths of combining both the quantitative and qualitative approaches (Creswell, 2014). When deciding on attributes to include in a choice experiment, authors can use techniques ranging from purely theoretical approaches to qualitative methods (Timmermans, Van der Heuden and Westerveld, 1982) cited in Glumac and Wissink (2018). When designing such DCE, Kløjgaard et al. (2012) highlight the importance of a thorough qualitative process, as a less thorough one would result in a less useable and valid design. This study followed a mixed-method approach, building on the literature on analysing consumer preferences for RE technology and policy (Kalkbrenner, Yonezawa and Roosen, 2017; Sagebiel, 2017; Kubli, Loock and Wüstenhagen, 2018; Lienhoop, 2018).

The study commenced with a qualitative phase, drawing on findings from the literature review and exploratory semi-structured interviews with real estate agents in Nigeria. This was based on guidance on best practices for SP studies (Bridges *et al.*, 2011; Johnson *et al.*, 2013; Johnston *et al.*, 2017) and previous research (Özbafli, 2011; Oseni, 2015, 2016; Glumac and Wissink, 2018; Bao *et al.*, 2020). The qualitative phase served the purpose of outlining attributes that residents look out for when deciding on a new home and the experiences of real estate agents regarding backup energy usage in residential buildings.

This initial qualitative phase guided the design of the quantitative phase. Specifically, it informed the elicitation of relevant attributes and levels to include in a discrete choice experiment contained in a survey of residents living in estates in Ibadan, a Nigerian city (outlined in Section 3.6). In addition to aiding the choice experiment design, the qualitative phase provided insights into the value that housing residents place on dwelling in environments with reduced air and noise pollution. In the quantitative stage, data from the survey were analysed using econometric analysis of choice data.

3.3.2. Study Location

Nigeria is divided into 36 states and the federal capital territory of Abuja. Each state is divided into three senatorial districts containing several local government areas (LGAs). Oyo State was chosen because it is home to Ibadan. With a population of 3.1 million[14], Ibadan city is the largest metropolitan geographical area in West Africa, home to 45 per cent of Oyo state's population (World Bank, 2014). The metropolis comprises the city of Ibadan (Ibadan urban) and surrounding suburban districts (semi-urban Ibadan). The Ibadan urban consists of five LGAs in the core area of Ibadan city[15], while semi-urban Ibadan constitutes the six LGAs[16] in the periphery of the Ibadan metropolitan area (Wahab and Falola, 2016). The interviews were conducted with real estate agents located within the Ibadan urban area as the research is specifically focused on the urban residents. The Ibadan urban area is also home to various housing estates with residents that often self-organise themselves through estate associations, making it an interesting case to explore. As outlined in Section 2.3.4, given the broad neglect of the government at the local level in providing infrastructure and amenities like security in residential neighbourhoods, residents organise themselves in estate associations. Estate associations in Ibadan are actively involved in the provision and maintenance of amenities such as neighbourhood security, waste disposal/management services, provision of street lights, electricity transformers, community potable water, and road maintenance, amongst others (Wahab and Adetunji, 2015; Fateye *et al.*, 2021).

Previous research by Adedeji (2016) on electricity demand in Ibadan found two distinct periods of household energy demand; peak and off-peak periods. The peak period was characterised as a period with very high demand for electricity service provision, typically between 6.00 am and 9.00 am and between 18.00 pm and 12.00 pm. Conversely, the off-peak period was characterised by low demand for electricity services,

[14] 2013 estimate based on (World Bank, 2014).

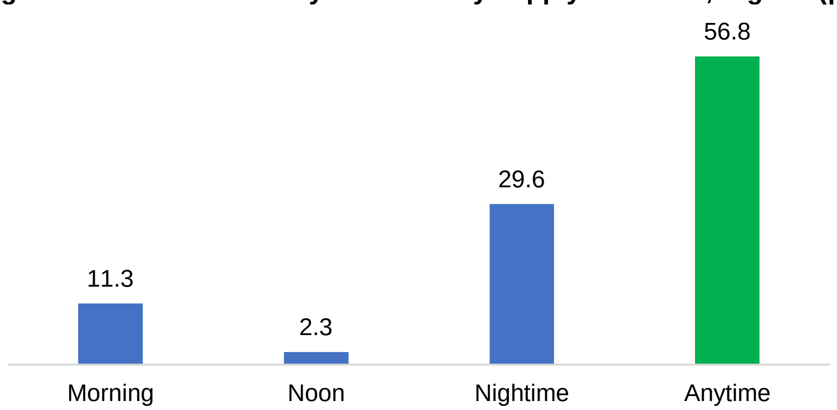
[15] These are Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East, and Ibadan South-West LGAs.

[16] These are Ona-Ara, Ido, Oluyole, Akinyele, Egbeda and Lagelu LGAs

typically between 10.00 am and 4.00 pm, when residents are at work or away from home. The study also found that demand for energy services in a typical household in Ibadan commenced in the morning around 5.00am to 6.00am for services such as lighting, ironing and water heating demands for baths, bread toasting and use of microwave amongst others. Demand in the midday was largely for entertainment/recreational activities of those present in the house with the use of electric fan for cooling and, in some cases, air conditioning systems and use of refrigerators for food preservation all around the clock. Demand at night was primarily used for lighting purposes and to extend the hours of the day. Other uses included cooling to get maximum sleeping comfort; communications and information services (charging of phones/handsets, listening to news); entertainment via watching television and other activities, like washing machines and microwaves in households with such. However, the inadequacy of electricity provision during peak periods forced households to switch and shift to other forms of energy such as generators.

On the supply side, the survey by Adedeji 2016 found supply timing to be erratic, and unpredictable see Figure 3-2 below. The study showed that there was no predictable period of electricity availability during the day. The inadequate quantity of electricity often resulted in households selectively using other forms of energy in the absence of electricity, and therefore, a movement of households down the bottom of the energy ladder.

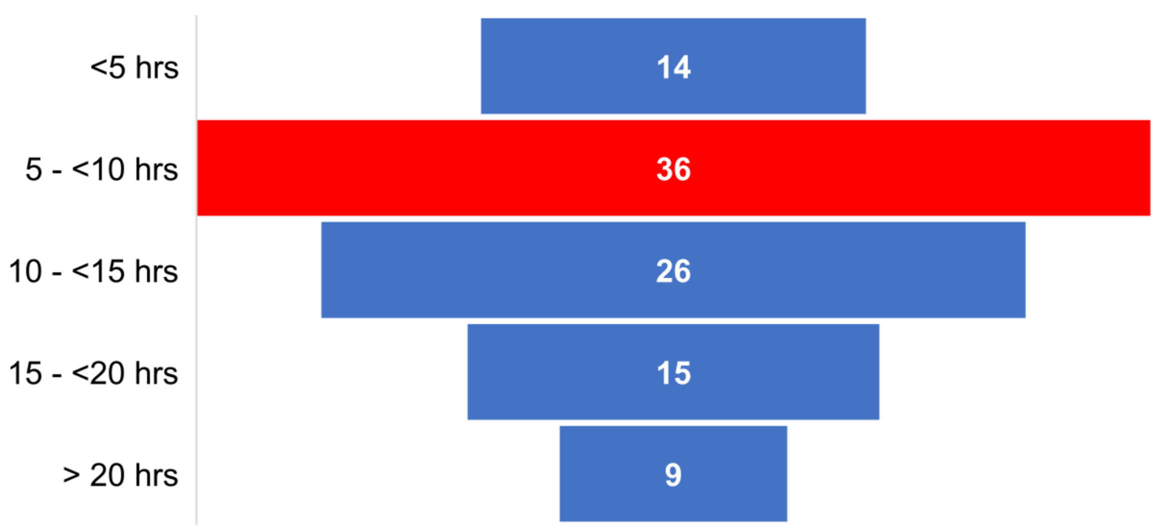
Figure 3-2: Time of the day of electricity supply in Ibadan, Nigeria (per cent)



Source: Adapted from Adedeji (2016)

Similarly, the number of hours of electricity supply in Ibadan is also very limited. Data from fieldwork conducted in this thesis shows the average hours of grid electricity supply in Ibadan to be around 5 to 10 hours daily (see Figure 3-3). Although many households desire to use electricity for various services, such as to power appliances, such services are typically not enjoyable due to the incessant blackouts. Households also suffer damages to electrical appliances from low voltage and supply fluctuations. These damages are often without any form of compensation from the electric utility. Ibadan has significant potential for using rooftop solar PV to meet energy needs. In terms of solar energy availability, a technical evaluation on the potential for rooftop solar in Ibadan Nigeria, by Ayodele, Ogunjuyigbe and Nwakanma, (2021) showed the significant potential for rooftop solar PV in Ibadan. The study estimated the annual solar energy harvestable on rooftop was estimated to be about 6.7 TWh/year.

Figure 3-3: Average hours of grid electricity supply in Ibadan (per cent)



Source: Field Survey

Part I

This sub-section outlines the qualitative research method used in this study. It outlines the study location, data collection method, interview approach and analysis. It ends by providing an outline of the ethical considerations in this study phase.

3.4. Qualitative Research Method

3.4.1. Method of data collection / Sampling Technique

The purposive sample method was employed as participants were selected based on their status and expertise as real estate agents and realtors. Being a non-probability sample determined based on the characteristics of a population and the study's objective, the purposive sampling method was considered appropriate to gather insights into the nature of the phenomenon being studied (Robson, 2011). In this case, the backup energy attributes residents seek when choosing a home. It is also considered applicable in this study because real estate agents and solar companies are vital to understanding how solar systems can be adopted among their residential clients in Nigerian cities.

Purposive sampling has limitations, including subjectivity and the validity of generalising findings to a broader population (Battaglia, 2014). To reduce subjectivity and ensure representativeness, the nature of respondents was discussed with members of the supervisory team. Participants in the research were identified by examining online directories of real estate agencies and estate developers in Ibadan. These were then contacted by telephone, and interviews were sought with them. Those who were granted permission for interviews participated in the research.

The real estate agents were selected as respondents for the qualitative section, for the following reasons. First, at the time the research was being designed, the consideration was that real estate agents were best placed to provide insights on the nature of backup energy use, given their familiarity with various types of houses and the corresponding energy needs of such houses. Second, the interviews with the real estate agents were also sought, so they could provide some clarity on whether to focus on residential homes rather than multi-occupant homes which was the notion at the time of designing the research, before designing the field survey.

3.4.2. Characteristics of the respondents

Eight experts were interviewed in June 2018, with seven face-to-face interviews, while one respondent (a real estate agent) sent responses to the questions via email. Table 3-1 lists the participants using pseudonymised names. Of the seven face-to-face interviews, six were with real estate agents, and one was with a solar company representative. By sex, there was limited participation of female respondents as only two out of the respondents were female. This is primarily because the real estate industry in Nigeria is generally dominated by male professionals (Oladapo, 2017; Oluwunmi *et al.*, 2017), however in hindsight, the research could have considered further ways to identify female real estate agents to interview through snowballing approach. This would have further allowed for diverse views and perspectives among the study respondents.

Table 3-1: Characteristics of participants

Participant pseudonyms	Category	Sex
Akin	Real estate agent	Male
Bayo	Real estate agent	Male
Chike	Real estate agent	Male
Deji	Real estate agent	Male
Enitan	Real estate agent	Female
Femi	Real estate agent	Male
Gbenga	Real estate agent	Male
Ige	Solar energy company	Female

3.4.3. Interview Approach

The interviews with real estate agents commenced by asking warm-up questions which focused on the nature of buildings the real estate agents have available to rent, attributes of homes they showcase to tenants and attributes that their residential clients consider when deciding to rent a home. The interviews then narrowed down on the energy considerations of tenants when deciding on a house. The interviews discussed the nature of backup energy provision, including clients' preferences for clean and quiet backup energy. The interviews also examined the perceptions of estate agents regarding clients’ interest in clean and quiet housing.

The interview with the solar company broadly focused on investigating the perceptions of important decision-makers regarding the adoption of solar energy in residential estates. Furthermore, it also investigated experiences relating to requests residential clients make about having specific hours of electricity from the solar systems. The interview also explored attributes of solar energy that the company showcases to its clients.

The interviews took a semi-structured format, where participants responded and discussed answers to various open-ended questions posed by the researcher based on an interview question guide. The semi-structured format was chosen because it allowed multiple aspects of the issue to be explored, with follow-up questions to probe further. The interviews lasted between 30 minutes to 1 hour and were recorded with the respondents' permission. Notes were also taken during the interviews. The interview guide, which contains a description of the questions asked, can be found in Appendix A4. Using the interview guide allowed uniformity in the questions posed to various respondents. However, sometimes questions did not follow the order in the guide because some respondents covered some issues in their responses to earlier questions. As much as possible, those questions were still asked to ensure they were adequately covered. Furthermore, to validate and ensure the accuracy of their responses, answers were repeated to the respondents.

3.4.4. Interview Analysis

This qualitative data analysis followed the thematic analysis approach outlined in Braun and Clarke (2006) to identify and concisely describe emergent themes and patterns from the interviews. Thematic analysis was chosen because of its flexibility and ability to identify, analyze, and report patterns (themes) within data (Braun and Clarke, 2006). Another reason why the thematic analysis was chosen is its ability to convey experiences, meanings, and participants' reality (Braun and Clarke, 2006). Another benefit of this approach is that it “offers an accessible and theoretically flexible approach to analysing qualitative data” (Braun and Clarke, 2006, p. 101).

Braun and Clarke (2006) recommended the six phases of thematic analysis (1). Being familiarised with the data (2). Generating initial codes (3). Searching for themes (4). Reviewing themes (5). Defining and naming themes (6), producing the report. The interviews were transcribed and initially coded in Microsoft Word and analysed using NVivo 12, a qualitative data analysis software (QSR, 2015). I present how I carried out the six phases below.

For the first phase, I familiarized myself with my transcripts through repeated reading whilst searching for meanings, taking notes and marking ideas for coding (Braun and Clarke 2006). The coding process is essential as it aids in organization, preventing data overload, and conceptualising (Walliman, 2006). At the end of each interview day, extra notes of crucial points reflected strongly in the analysis were made. Phases two and three started with generating initial codes and searching for themes, respectively (Braun and Clarke 2006). The production of initial codes from the data was essential to understanding the emergent themes. At this preliminary stage, the interview transcripts were read in detail without any theoretical assumptions to gain familiarity with the data. Initial themes were highlighted and coded in Microsoft Word. The transcripts were then imported to NVivo for further coding.

In phases four and five, I reviewed and named the themes (Braun and Clarke 2006). At this stage, I revised some themes and merged them to form a theme and broke some other themes down into separate themes in line with the recommendations of Miles and Huberman (1994)[17]. By defining and refining these themes, I identified their significance to the study and various aspects of the data captured by these themes. A total of 57 codes[18] emerged from this process. These codes were placed in five categories. For the sixth and final phase, findings on the emergent themes were

[17] They suggest that qualitative data analysis should follow a concurrent process of data reduction, data display and conclusion drawing/verification.

[18] The code sheet is attached in the appendix

written up. Themes and categories that emerged from the analysis were interpreted and are presented in Chapter 4.

3.4.5. Credibility and trustworthiness

Reliability and validity are essential criteria to establish and assess the quality of research done using quantitative methods. However, due to the emphasis that reliability and validity place on measurement, the inability to replicate social settings, and varying accounts of social realities by researchers, authors such as LeCompte and Goetz (1982) argue that it might be inappropriate to apply these to qualitative research. In qualitative studies such as this one, Guba and Lincoln (1994) put forward trustworthiness and credibility as two primary criteria that can be used to assess research quality. To ensure trustworthiness, this research employed measures such as respondent validation by relaying the research findings to participants to ensure that the results depict their perspectives and experiences (Bryman, 2008, p. 377). Another measure to ensure trustworthiness is by describing the context (Nigeria) where this research is taking place to allow others to make informed judgments on its transferability. This study also took steps to ensure dependability. All stages of the research process (including problem formulation, selection of participants, field notes, interview transcripts, data analysis decisions, etc.) are well documented to keep an audit trail of the research. This research took steps to represent different viewpoints among stakeholders to ensure credibility. Employing the dual use of computer-assisted data analysis via NVivo and manual checks on the analysis in line with the study done by Jugder (2016) also improved the trustworthiness and credibility of this research.

3.4.6. Interview Ethical considerations

This phase of the research was carried out with approval from appropriate UCL ethics boards, and the project was compliant with the General Data Protection Regulation. The participants provided their informed consent to take part in the study after reading an information sheet with a plain English explanation of the data collected if they agreed to participate. The information sheet also clearly explained what the data would be used for. This information included explaining that their words may be quoted for illustration in this thesis, conference presentations, and other publications, but outlined how such quotations will not disclose their identity or the identity of their organisation. The information sheet emphasised the lack of obligation to participate and the channels available for withdrawing from the study and lodging any complaints arising due to the research. If the participants agreed to participate in the study, they signed an informed consent form to indicate that they had read and understood the information sheet. The information sheet and informed consent form are given in Appendix A2 and A3. There were no direct benefits to the participants from taking part in the research; however, the participant information sheet outlined those potential benefits of research findings on the marketing strategies of the real estate agents. Upon completing the interviews, participants were thanked for participating in the research. The research was designed not to harm the participants or the researcher. Risks to physical harm were addressed and mitigated by completing appropriate risk assessments, which were completed before the field trip. Risks to reputational harm to the participants was mitigated by ensuring that the participants were non-identifiable in the presentation of all results from the project.

Part II:

3.5. Quantitative Research Methods

This sub-section provides details on the quantitative research methods used in this study. It outlines the approaches to measuring consumer preferences, details the discrete choice method employed, the survey design, data collection and analysis. It ends by providing an outline of the survey's ethical considerations.

3.5.1. Approaches to measuring consumer preferences

There are numerous methods used to study RE valuation. These can be grouped into five main categories; SP, revealed preference (RP), portfolio analysis, energy analysis and various other economic but non-welfare-based methods (Menegaki, 2008). SP employs methods based on surveys and hypothetical scenarios, while the RP method uses actual consumer expenditure data on goods related to the service of interest[19]. Under the SP approach, WTP for RE is usually evaluated by carrying out a DCE or using the CV method.

3.5.2. Revealed Preference Approach

The RP approach refers to methods based on ex-post analysis of actual decisions. For example, methods used to analyse actual purchase decisions of consumers in a grocery chain like Tesco. Although revealed preference methods have clear advantages, they also have several statistical shortcomings (Calfee, Winston and Stempski, 2001; Freeman, 2003). For example, market data is not always available to estimate consumer preferences; and even if such data are available, they may be too correlated and thus frustrate empirical procedures. Also, revealed preferences data do not allow for estimating a commodity's value that is partly unrelated to the consumption of complementary goods. By contrast, SP methods enable researchers to measure this value, and it is often referred to as "existence value", "passive use value", or "non-use value" (Zalejska-Jonsson, 2014).

3.5.3. Stated Preference Approach

The SP approach refers to a family of techniques that use individual respondents' statements about their preferences in a set of alternatives to estimate utility functions (Kroes and Sheldon, 1988; Rose and Bliemer, 2009). SP data is collected through experimental situations or surveys in which respondents are presented with choice problems of a hypothetical nature. It is also described as the direct approach, as the data comes directly from the respondents, the hypothetical decision-makers. As such, this approach does not represent the actual decisions or behaviour of the respondents. Instead, it describes how the decision-makers state they would behave.

Advantages of SP data include its ability to indicate how individuals will behave in a scenario or situation that is yet to exist (Johnson *et al.*, 2013; Tinch *et al.*, 2019), such

[19] It is important to note that stated WTP might not translate to actual consumer behaviour and there is a robust literature that examines the differences between stated and actual WTP.

as creating a new technology type, in this case, a form of backup electricity. Hence, if the research objective is to exemplify consumers' behaviour towards a product that does not exist, the SP approach is considered suitable for such analysis (Calfee, Winston and Stempski, 2001; Chen, Honda and Yang, 2013). Another strong point of the SP approach is that it is suited to data with little or no variation (Bridges *et al.*, 2011; Chen, Honda and Yang, 2013; Janssen, Hauber and Bridges, 2018). The data collection instrument can be designed to result in the data having the desired variation. The primary drawback of SP data is that actual behaviour by respondents might differ from what they have stated because the respondent might feel they are expected to behave in a specific manner or because they might not know how to respond (Matyas, 2020).

Several studies have expressed concerns over the ability of SP approaches to predict actual purchase behaviours (Aguilar and Vlosky, 2007; Bull, 2012; Namkung and Jang, 2017). However, some studies have opined that many of the observed problems with the SP approach can be corrected by careful study design and implementation (Calfee, Winston and Stempski, 2001; Carson, Flores and Meade, 2001). For example, Byrnes et al. (1999) compared hypothetical WTP statements with actual payment commitments. They discovered that the CV method can accurately predict an individual's WTP but that it is an unreliable estimator of the specific individuals that will eventually pay.

3.5.3.1. *Justification and limitations of the Stated preference method*

This study employs the SP approach, focusing on investigating the value of "non-direct goods", including the attributes of solar energy and interest in P2P energy trading, for which data on actual individual decisions in Nigeria is not readily available. The SP approach was taken due to three reasons; timing, data availability and suitability for examining interest in P2P energy trading.

Starting from the timing perspective, in 2017, when this research commenced, to the best of my knowledge, I was not aware of how I could get like highly reliable revealed preference data to answer the research questions. Thanks to my examiners, I now understand that I could also have carried out a revealed preference study via a survey, but at the time of conducting this research, I was not aware of this possibility.

On data availability, to the best of my understanding, there was limited publicly available data on solar PV adoption at a granular level that allowed for the investigation of preferences. Whilst there is some data on the adoption of solar systems in Nigeria provided by the GOGLA as outlined in Chapter 1, this data doesn't give detailed information about the nature of consumers, such as demographic information, and location, that could be used to tease out information about preferences. Furthermore, linked with the timing point above, I only became aware of the GOGLA data towards the end of my PhD when I was trying to write up my thesis.

Similarly, an existing household-level survey by the Nigerian National Bureau of Statistics and the World Bank only has a few questions about energy use[20] but doesn't provide granular information about the nature of such use, especially as it relates to the use of solar energy for backup electricity. Furthermore, the most recent Multi-Tier Framework survey on Nigeria conducted in 2018, which has in-depth coverage of energy usage in depth only covers North-West Nigeria (World Bank, 2018)w.

Third and most importantly, the choice of the SP method was most suitable for examining interest in P2P energy trading, given that this information does not exist. As P2P energy trading is not existent in the Nigerian energy sector, the use of the SP method is advantageous because when examining technology that does not exist and is likely uptake among potential consumers, the SP approach is the most appropriate approach.

As outlined above, the key limitation of this approach is that it does not reflect actual purchase behaviour and actual real-world behaviour. However, the use of the SP approach is useful to tease out what the likely preferences and the nature of interest for P2P would be within the research context.

[20] The only household energy related question in the General Household Survey-Panel questionnaire are related to asking if households made any energy related purchases such as paying for electricity, gas, cooking fuel, petrol, diesel etc

3.6. Discrete Choice Experiments

According to Louviere (2001), DCEs typically comprise: (i) a fixed set of choice options; (ii) a set of attributes that describe the potential differences in the choice options; (iii) a set of levels or values assigned to each attribute to capture the range of variation in that attribute; (iv) a sample of subjects who evaluate all or a subset of the choice sets in the total experiment and choose one of all the possible options available to be chosen in each set.

Respondents are initially asked to choose their most preferred option from two or more alternatives and then repeat this process over different choice sets (Quaife *et al.*, 2016). To maximise the statistical efficiency of the experimental design, there is a systematic variation of attribute levels between choice sets. In each choice set, the respondents will pick the option that gives them the most benefit. Therefore, the choices they make point toward an underlying utility function. Econometric analysis of DCE data can then be used to estimate these utility functions, which quantitatively weigh the value placed on each attribute. An in-depth analysis of these preferences can also be carried out when variables that capture socio-demographic information of respondents are included as explanatory variables in these functions (Hensher, Rose and Greene, 2005).

DCEs can quantitatively single out an individual's valuation of specific attributes (such as the clean and quiet benefits of using solar PV for backup electricity) and determine the strength of consumer preference for an attribute relative to another (such as price) (Sundt and Rehdanz, 2015b; Potoglou *et al.*, 2020). They can also be used for forecasting demand, generating WTP estimates and potential uptake of new products and services (Aizaki and Nishimura, 2008). They also present policy-relevant findings by understanding attributes essential to people, the trade-off between attributes, and the simulation of various possible product uptake scenarios (Mangham, Hanson and McPake, 2009). Other strengths of DCEs include the advantage that a properly designed study is easy for participants to understand and the results are relatively easy to interpret (Mariel *et al.*, 2021).

However, DCEs also have shortcomings, including the hypothetical nature of choices and consequent susceptibility to hypothetical bias and strategic behaviour (Hensher, 2010). A good experimental design ensures that the choices presented mirror decisions that respondents face in real life to overcome this bias. They also have limited external validity and applicability to other settings different from those carried out (Lancsar and Swait, 2014). They are also viewed as a somewhat simplified and simplistic approach to evaluating choices compared with real-life decision-making (Rommel, Sagebiel and Müller, 2016; Sagebiel, 2017). Furthermore, DCEs are complex to design and analyse; hence the importance of preliminary qualitative work to shape attribute design cannot be overemphasized (Coast *et al.*, 2012; Vass, Rigby and Payne, 2017). Adequately designed surveys are also less cognitively demanding for participants.

3.6.1. Using DCEs to Elicit Consumer Preferences

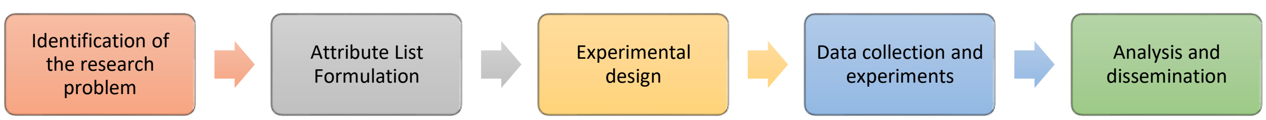
DCEs are used to elicit consumer preferences (Oerlemans, Chan and Volschenk, 2016), relying on the SP methods based on the classical random utility theory (Lancaster, 1966; Louviere, 2001). Unlike revealed preference (RP) methods based on ex-post analysis of actual decisions, DCEs are used when there is scant information on observed behaviour. DCEs are usually implemented through surveys where individuals are typically confronted with making their preferred choice between two or more alternatives (e.g. products). These alternatives are described by their attributes (e.g., price, quality, and quantity (Lancsar, Fiebig and Hole, 2017)). These attributes take one of several levels that describe ranges over which the attributes vary (e.g. for a price attribute, this could range from £100-£1,000).

Based on DCE data, econometric methods can be used to analyse key drivers of consumer preferences quantitatively and predict future behaviour. Such data analysis can illuminate the relationship between specific attributes and respondents' choices. It can also show how changes in attribute levels affect the average respondent's utility or WTP. DCEs differ from another SP approach, the Contingent Valuation (CV) method, as the CV keeps the attribute values of the product in question fixed among all individuals. In contrast, DCEs keep them experimentally varied (Oerlemans, Chan and Volschenk, 2016). Furthermore, DCEs also generate information about the case where the product is not chosen, while CV collects information about the selected product.

DCEs have been applied in various fields, such as health economics (Lancsar *et al.*, 2013; Clark *et al.*, 2014; Mühlbacher and Johnson, 2016; Quaife *et al.*, 2018); transportation (Casey, Kahn and Rivas, 2008; Lagarde and Blaauw, 2009; Hackbarth and Madlener, 2016; Mayas and Kamargianni, 2017), environmental valuation (Schaafsma *et al.*, 2014; Gamel, Menrad and Decker, 2016; Rakotonarivo, Schaafsma and Hockley, 2016; Mariel, Hoyos, Meyerhoff, Czajkowski, Dekker, Glenk, Jacobsen, *et al.*, 2021), marketing (Louviere, Pihlens and Carson, 2011; Hess and Daly, 2014; Breidert, Hahsler and Reutterer, 2015), and energy economics (Borchers, Duke and Parsons, 2007; Sundt and Rehdanz, 2015a; Cardella, Ewing and Williams, 2017; Kubli, Loock and Wüstenhagen, 2018).

Following Louviere's (2001) and Ben-Akiva and Lerman's (1985) recommendations, the choice experiment is carried out in five stages, shown in Figure 3-4 below.

Figure 3-4: Discrete Choice Experiment Steps



3.6.2. Identification of the research problem

Identification of the research problem formed the basis of the exploratory research work conducted between September 2017 and May 2018. The main issue the research aimed to address is the challenges associated with using generators to meet backup electricity needs in Nigeria and the role of clean energy alternatives like solar PV and P2P energy trading in addressing this problem, as outlined in the introductory chapter. As seen in Section 3.4 and Chapter 4, which outlined the main findings from the exploratory research work, clean and quiet attributes of solar energy are of importance to residents and therefore shaped the selection of attributes considered for selection in the study as described in the next section.

3.6.3. Attribute List formulation

Identifying relevant attributes in this study involved an initial qualitative phase as outlined in Section 3.4 and a review of the literature on RE using SP methods. This process was based on recommendations in the literature on including qualitative research in attribute development and selection for DCEs (Coast and Horrocks, 2007; Coast *et al.*, 2012). This study contained two cost attributes, one for house price and the other for backup price. There have been discussions in the DCE literature that the inclusion of two cost attributes might increase the response error variance, indicating that the choice responses are less deterministic (DeShazo and Fermo, 2002; Islam, Louviere and Burke, 2007; Pedersen *et al.*, 2011; Dellaert, Donkers and Van Soest, 2012). However, Sever et al. (2018) demonstrated in their study that the effect of an additional cost attribute is the same as the expected effect of including any other choice attribute. Hence the influence might not be as relevant as previously argued in the literature.

The attribute selection was also guided by the research questions. For example, to answer *RQ1 (what are user preferences for solar PV as a form of backup electricity in a Nigerian residential setting?)*, the study attributes were informed by empirical studies outlined in Section 2.1 that broadly showed that some of the factors that motivate people to adopt solar PV are related to concerns for the environment, technological interests, and financial considerations such as cost (Vasseur and Kemp, 2015; Ugulu, 2016; Bondio, Shahnazari and McHugh, 2018; Palm, 2020).

On the energy trading attribute, this was informed by the quest to further *understand the potential benefits that influence preferences for P2P energy trading among residential consumers,* as outlined in RQ2. As the literature review in Section 2.2 showed that whilst limited, empirical evidence from surveys with prospective prosumers has been used to depict preferences for P2P energy trading (Sorin, Bobo and Pinson, 2019; Ableitner et al., 2020; Hackbarth and Löbbe, 2020; Hahnel et al., 2020;

Georgarakis et al., 2021). Some of these studies show the need for further exploration of energy trading as it relates to individuals. As Mengelkamp *et al.* (2017) concluded, "*The socioeconomic incentives of community members to participate in localized energy markets require further research to adapt the market design to facilitate an efficient allocation of local energy generation*."

Furthermore, the theoretical framing of exchange by Gudeman (2008, 2016), as outlined in Section 2.3.3, revealed that in a market, people exchange goods, buying and selling at the best price available. Drawing on the empirical and theoretical literature, this study added some nuance to the inclusion of the energy trading attribute by further distinguishing between preferences for buying and selling.

Furthermore, the inclusion of the attributes aided the investigation of willingness to pay estimates in Section 5.3.4. It is important to note here that, as shown above, the inclusion of two cost estimates is justified on the basis that it allows for a disentangling of the preferences when accounting for house price and backup price. However, an alternative approach would have been to use a single additive cost attribute which accounts for both cost attributes on the basis that they are fixed costs. The final list of attributes and their respective levels are described in Table 3-2 below.

Table 3-2:Study Attributes and levels

Attribute	Levels	Explanation
Backup type permitted (Backup)	Generator	Status quo option; therefore, no cost is involved
	Inverter	No generator is allowed, and backup electricity provision is via inverter and battery storage
	Solar	No generator is allowed, and backup electricity provision is via rooftop solar PV, inverter and battery storage
Noise and air pollution (Pollution)	None	Status quo option
	Low	This variable captures the amount of generator and related noise in the estate. It also captures how residents view the amount of air pollution in the estate, primarily resulting from generator exhaust fumes. The 'low' level of pollution depicts instances where residents experience moderate noise and air pollution, while the "High" level depicts a severe pollution level.
	High	
Energy Trading (Trade)	No energy trading (*none*)	Status quo option; therefore, no cost is involved
	Buying electricity from neighbours	Participants can buy energy from other residents
	Selling electricity to neighbours	Participants can sell excess energy to other residents
Cost of the house (House price)	₦0	Status quo option; therefore, no cost is involved
	₦10million (US$ 32,583)[21]	This variable captures the cost of the house being purchased in the new estate
	₦20million (US$ 65,166)	
Initial cost of the backup energy system (Backup price)	₦0	Status quo option; therefore, no cost is involved
	₦1million (US$ 3,258)	This variable captures the cost of purchasing the backup energy option
	₦2million (US$ 6,517)	

[21] The exchange rate used in this study is US$ 1 = ₦306.91 and is based on the average official exchange rate for 2019, the year when the survey was conducted. Rates are obtained from World Bank, 2021.

3.6.4. Experimental Design

Designing and administering the DCE is perhaps the most challenging part of DCE studies, as Lancsar et al. (2017) highlight that reaching the stage of having an amenable and useful dataset emanating from a DCE is significant and should not be underestimated. This study paid careful attention at this experimental design stage, and an appropriate design was carefully selected based on the recommendations from key authors in the literature, such as Bridges et al. (2011); Johnson et al. (2013).

In the DCE, respondents are asked to indicate which they prefer between two housing options and the status quo. There are five attributes with three levels each, meaning that there is a 3^5 problem. Hence, a full factorial design for this problem yields 360 alternatives (possible combinations), which is quite numerous for a survey to handle, even if they were partitioned into blocks administered to groups of respondents. Hence this study used an orthogonal fractional factorial design with fewer runs and is used in the literature to deal with designs of this nature (Louviere, 2001; Jaynes, Wong and Xu, 2016; Oyinbo *et al.*, 2019). The orthogonal design was implemented in R software (R Development Core Team, 2019) using the *support.CES* package developed by Aizaki (2015). The package was used to combine various attribute levels into different pairs of mutually exclusive hypothetical home options with backup energy evaluated by respondents.

An orthogonal design is chosen based on recommendations in the literature on DCE experimental design use an orthogonal design if there is no information on prior estimates, as it is the most efficient in this case (Rose and Bliemer, 2013). The authors also note that if there is no information on prior estimates, it is good practice to assume that the prior parameter estimates are all equal to zero. The orthogonal fractional factorial DCE design also overcomes the multicollinearity problem as it ensures no correlation among the attributes (Kim, Park and Lee, 2018).

3.7. Questionnaire Design and Survey Administration

3.7.1. Choice format

There are two categorizations for DCEs in the literature based on the number of alternatives per question and the type of alternatives in the choice sets, respectively (Aizaki, Nakatani and Sato, 2014). In the first category, DCEs can either be binary or multinomial[22]. In binary DCEs (BDCE), the questions that respondents need to answer consist of only two alternatives, and it is mostly applied in the health economics literature. Conversely, in multinomial DCEs, respondents need to answer questions comprising three or more alternatives. In the second category, DCEs can be subdivided into three categories: DCEs with an opt-out option, DCEs with a forced-choice format, and DCEs with a common base option. In DCEs with an opt-out option, respondents can decide not to choose any of the alternatives presented, or in the case of the BDCE, decide not to select the only alternative presented.

In DCEs with a forced-choice format, respondents must choose one of the alternatives presented, with no opt-out option available to them. Finally, in the DCE with a common base option, the same option appears in all choice sets. This common base option could be a status-quo option, a likely situation with no intervention or policy or a standard product alternative (Aizaki, Nakatani and Sato, 2014).

Furthermore, DCEs can also be sub-classified based on how they are presented to respondents, in other words, on the type of labelling employed, namely, the labelled DCE (direct labelling) and the un-labelled (generic) DCE (Aizaki, Nakatani and Sato, 2014; Vass, 2015). As the name implies, labelled DCEs have the names of the alternatives presented to respondents to distinguish each alternative in the choice set. Labelled DCEs can also comprise an alternative-specific attribute (ASA) that refers to an attribute that is only included in one alternative. In the un-labelled DCE, generic names are given to each alternative. In the case of the un-labelled design, the ASA is a generic attribute included in every alternative. Direct labelling is advantageous as it

[22] In a similar manner to discrete choice models which can be multinomial choice models (like the conditional logit model) and binary choice models (such as the binary logit model).

adds some realism to the choices presented (Kruijshaar *et al.*, 2009). However, this could also distract respondents' attention from the attributes.

This study uses a multinomial DCE with three options presented to respondents. The first two options are alternatives that vary based on the level, while the third option is the status quo option. Furthermore, the DCE uses an un-labelled question format. The use of the unlabelled format for the different types of homes (Option A, Option B) allows respondents to focus on the attributes being evaluated (Bliemer, Rose and Chorus, 2017; Su *et al.*, 2018).

The common base DCE choice format is used in this study with an opt-out alternative of “status quo – current house” because the forced choice format is not considered appropriate for a study of this nature (Vass, 2015). The inclusion of this status-quo option in each choice set also allows for comparing respondents' stated preferences with the current situation where generators are allowed (Longo, Markandya and Petrucci, 2008). Such a comparison is necessary when researchers want to compute the value (WTP) of each alternative and estimate the unconditional demand for new products, in this case, the energy trading option (Hanley, Mourato and Wright, 2001; Longo, Markandya and Petrucci, 2008). The status quo option (Option C in the DCE) always contained the same attribute values across all the choice cards. The status quo (or opt-out option) in the DCE was about respondents maintaining their current homes and using generators for backup energy provision where they do not have the possibility to engage in energy trading. The inclusion of a generator as the backup attribute in the opt-out alternative is further justified as the results in Chapter 5 show a high prevalence of generators among survey respondents.

3.7.2. Steps to ensure a good DCE Design

A good DCE design ensures that the choices presented are relevant and meaningful to participants, and to do this, the following steps were taken. First, the choice tasks and attributes were explained to participants using a clear and concise information sheet written in plain English for ease of understanding. Second, enumerators were available to explain any unclear aspects of the information sheets. The pilot study also helped clarify aspects of the questionnaire that were unclear to participants. Third, the inclusion of the opt-out status quo option also made the options realistic for respondents, reducing the potential bias from forced-choice options and avoiding overestimating demand for new products (Lancsar, Fiebig and Hole, 2017; Quaife, 2018).

3.7.3. Pilot Testing of DCE

The DCE was initially piloted with a small sample (9 participants) to determine the appropriateness of background questions and the choice tasks. The pilot test involved testing out the DCE with residents in an estate in Ibadan. The pilot study involved selecting a residential estate with primarily owner-occupied homes. Respondents at the pilot consisted of households that attended the monthly estate association meeting at the selected estate. This served the purpose of testing and refining the data collection approach and developing prior estimates for further refinement of the design. However, whilst the pilot served the first purpose well, the second purpose was less successful as the results from the pilot study did not show any meaningful estimates to inform the use of a more efficient design. Reasons for this include the very small sample, which in hindsight, should have been larger. Nevertheless, the pilot study was useful in determining the appropriate representation of the attributes. It also helped to identify possible issues with the paper-based implementation of the DCE. This stage was also useful in creating a clear, relatable, relevant and clear choice set that participants could understand.

3.7.4. Questionnaire structure

The questionnaire starts by presenting the topic of the survey: people's opinions on various forms of backup energy as well as questions on the current use of backup energy. The first and second part of the survey presents questions on respondents' use patterns, experience, interests and expenditure on both grid electricity and backup energy. The second part examines residents' views on pollution and the health risks of using a generator in their residential estate. Here, respondents are presented with warm-up questions that examine their knowledge of the benefits and externalities of using different types of backup energy. The third part examines respondents' interests in energy trading. This part prepares for the hypothetical nature of the DCE to come in the next, as respondents are introduced to the hypothetical option of trading energy from solar systems installed in their homes. The fourth section is the central part of the questionnaire with the four choice experiment questions. Before the DCE questions, information is provided to describe the hypothetical choice of buying a house in a new estate.[23] The information describes four attributes that define the possible characteristics of the new home in a new estate, with emphasis on the energy characteristics.

The fifth part of the questionnaire collects the usual socio-demographic characteristics, including age, income, location[24], and gender. Demographic data is useful for analysing how preference for backup energy is shaped by personal characteristics and examining the heterogeneity of preferences among respondents. The sixth part of the questionnaire presented some debriefing questions[25] to gather views on how they found the DCE. An example of the questionnaire is included in Appendix A9.

---

[23] Initial versions of the questionnaire included a statement in this section asking respondents to focus only on the four attributes we consider and not to think of other elements that might characterize the decision to get a new home. That is to assume all other characteristics of the home that are not presented (such as safety, or distance to workplace) to be fixed. Based on supervisory feedback, this statement was omitted from the final version of the questionnaire due to considerations that it might confuse participants

[24] Location information relating to where people currently live is collected to determine if preferences are closely related to where they currently live

[25]Using a Likert scale.

Box 1: Example of a choice situation presented to respondents

- Imagine you are buying a house in a new estate.
- The houses vary in terms of the generator types that are allowed
- Some of the estates do not allow petrol/diesel generators; hence there is not much noise and air pollution
- In this estate, you can also buy and sell electricity with people in the estate
- In addition to the price of the house itself, you also need to consider the amount you will pay upfront to buy the backup electricity type you use
- I'm now going to ask you four questions where you select your most preferred house type.

Figure 3-5: Example of a Choice card presented to study respondents

Attributes of the house	Option A	Option B	Option C (Status quo)
Backup	Inverter	Solar	Generator
Pollution	Low	None	Yes
Energy Trading	Buying	Selling	Not available
House price	₦10M	₦10M	Same price as your current home
Backup price	₦2M	₦2M	Same price as your current generator
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

3.7.5. Participant selection and recruitment

The survey and DCE were administered among residents living in housing estates in Ibadan through a face-to-face survey using the purposive sampling method. Participants were identified and contacted through emails, telephone calls and letters to estate resident associations within the Ibadan urban area. Interested residents in these estates were invited to participate in the study and complete the questionnaires during their monthly estate association meeting. The surveys were administered to estate residents during such monthly estate association meetings between July – August 2019. A pictorial example of such meeting is available in Figure A-1.

The data collection was managed in conjunction with UI-LISA, a local statistical laboratory and data collection team at the University of Ibadan[26]. Research assistants from UI-LISA were hired as survey enumerators. They were trained to understand the details and nuances of the survey, with emphasis on the DCE. 1,024 questionnaires were distributed, and 655 questionnaires were retrieved and coded into spreadsheets, representing a response rate of 64 per cent. While cleaning the data, six questionnaire responses were dropped from the dataset used for analysis as they were determined to be invalid. After this process, 649 questionnaires were valid for analysis, representing 63 per cent of the original questionnaires distributed. As each individual in the sample faced four choice situations (each with three options), the final dataset used for the choice modelling estimation consists of 7,788 observations.

3.8. Data preparation and transformation

3.8.1. Data coding

The questionnaires were coded by trained data entry personnel from UI-LISA using an earlier provided template in SPSS. Spreadsheets were combined into a single data file by the UI-LISA coordinator. Coded entries were randomly cross-checked with the paper copies to ensure accuracy and consistency by the coordinator. I also carried out similar consistency checks to ensure the data were valid for analysis. Confusing entries or entries with mistakes in the spreadsheet were adjusted to reflect the actual responses by respondents.

The entries were coded using the variable-by-case data grid as specified by De Vaus (2002, p. 2), with each column representing a variable and each row depicting a case. Every cell contained the response of a case to a specific variable. Numeric codes were used for ease of statistical analysis over an alternative like alphanumeric codes, with

[26] www.lisaui.com

some of the questions[27] already pre-coded in the questionnaire to improve the accuracy of the data entry.

Non-responses were coded using a “dot” to depict that the respondent did not select any of the options for the specific question. As much as possible, the data entry personnel coded entries in detail instead of broad coding. This is because, with detailed coding, it is often possible to collapse entries at a later stage rather than to expand broad categories to determine finer details after broad coding (De Vaus, 2002). Closed questions where respondents could select multiple responses were coded using the multiple-dichotomy method, creating a separate dummy variable for each response.

3.8.2. Dummy Coding vs Effects coding

As the DCE and categorical questions in the survey were coded using the dummy coding method, it is important to justify the use of this method. Dummy coding or effects coding can be used when categorical coding responses to a DCE survey. Dummy coding, also known as indicator coding, involves coding the reference level equal to 0, and the presence of a qualitative level is set equal to 1. For example, suppose there is an attribute with *N* qualitative levels. In that case, responses can be transformed into a maximum of *N-1* dummy variables in which each dummy is set to equal 1 when the qualitative level is present and is set equal to 0 (the reference level) when not present (Bech and Gyrd-Hansen, 2005). The reference level/category refers to the omitted dummy variable. It is the category against which other dummy variables are compared (Hutcheson and Sofroniou, 1999, p. 86).

On the other hand, effects coding is an alternative to dummy coding, whereby the effects are not correlated with the intercept. Just like dummy coding, N-1 dummy variables are created; however, the reference level is set equal to -1 instead of 0. In this case, the comparison is between each dummy variable category and the average value of responses to that variable. Effects coding, also known as deviation coding,

[27] Questions in the questionnaire that used a Likert scale were pre-coded from 1-5 using the example provided in De Vaus (2002, p. 4)

is particularly useful to compare each dummy variable to the group average or when an analyst does not want to compare each dummy variable against a reference category. The key difference between the two forms of coding is the treatment of the reference level.

Whilst dummy coding has the advantage of being useful for comparing levels to a reference level, some authors (Bech and Gyrd-Hansen, 2005; Hensher, Rose and Greene, 2015) within the DCE literature argue that effects coding has an advantage over dummy coding as the latter could lead to regressors being correlated with the intercept term (in DCE, this is normally the alternative specific constant (ASC)), leading to wrong interpretation of the intercept. Alternatively, Daly et al. (2016) demonstrate that both forms of coding are theoretically equivalent and parameter values from a model employing one coding form can be transformed (post-estimation) to those from another one. Daly et al. argue that the confounding between dummy-coded ASCs and dummy-coded categorical variables does not really matter; rather, what matters is the difference across a level of given attributes and the comparison of those differences, not the type of coding employed. In sum, it can be concluded that both dummy and effects coding are equivalent as the type of dummy coding used does not affect the overall model fit. The key difference is in interpreting the statistically significant constant term and the distribution of differences between the dummy variables.

The *support.CES* package in R used to create the DCE design matrix in this study employs dummy coding instead of effects coding. To this end, the responses to the DCE in this study were dummy coded. However, it is noted that the alternative form of coding, effects coding, could have also been employed, but as stated earlier, Daly et al. (2016) point out that parameter estimates from dummy coding can easily be converted to that of effects coding.

3.8.3. Dealing with Double entries and missing data

In research surveys, missing values occur for various reasons, such as respondents not answering the questions, providing illegible answers, ambiguous answers, or when they are not required to answer the question (De Vaus, 2002, p. 64). Including these entries in the dataset used for analysis pose challenges as it can confuse real responses with non-responses, distort results, spoil the ordinal or interval character of a variable, and distort summary statistics and scale scores. Alternatively, excluding missing cases may also result in distorted samples and patterns, as the cases without responses may differ from cases with valid values. It can also result in the reduction of a sample size to a level that would affect the precision of estimates.

To deal with missing data, the first step employed was to determine the amount of missing data in the sample, with checks on the missing values on individual variables and the cumulative loss of cases across the sets of variables. This check revealed that in the dataset, the average number of missing values for individual variables was 18, representing 3 per cent of the responses to the respective questions. This means that most of the variables had a very low number of missing values. However, there were a few outliers, with seven variables having more than 60 missing entries. When these outliers were excluded, the mean number of missing values dropped to 16, representing 2 per cent of responses to the questions.

The DCE section had the most cases of missing data, as the variables with the four highest numbers of missing entries were all from this section. Likely reasons for this include the complexity of the DCE questions, as the debriefing section at the end of the questionnaire showed that it was the section that most respondents found difficult to understand. Other steps taken to deal with missing data include checking for missing values bias. The top four ranked questions in the survey with missing entries were the following: Question 39: N=113 (17.4 per cent), Question 38: N=108 (16.6 per cent), Question 37: N=104 (16.0 per cent), Question 36: N=88 (13.6 per cent). These four questions were the choice sets presented to respondents. Beyond these questions, the only other variable which had missing values above 10 per cent in the survey was Question 5, which asked if respondents had ever turned their generators due to concerns about the exhaust fumes, to which 13.4 per cent of respondents did not answer. However, this question was not included in the empirical analysis as a large proportion of respondents (63.3 per cent) had not turned off their generators for this reason.

Overall, the missing data checks signalled the relatively low number of missing entries in the dataset. Nevertheless, a decision had to be made to include or exclude these missing entries from the dataset. Three broad options were considered for dealing with missing data in this study. The first option was to drop variables with large cases of missing data outrightly; however, this was not chosen for any variable due to the relatively low number of missing entries, as discussed earlier.

The second option was to impute a value to replace the missing values through any of the following approaches: the series-mean approach, group-means approach, linear interpolation approach or the expectation-minimization approach, as discussed in De Vaus (2002, pp. 68–69). This option was not implemented to preserve the original values from the dataset. The third option - which was chosen - is to drop any specific case with a missing value on the variables used for analysis. Since the missing variables for the DCE questions were already above 10 per cent, the pairwise deletion approach was chosen over the list-wise deletion approach, as choosing the latter would have dropped too many cases from the analysis, which would have compromised the analysis. However, using the pairwise approach was carefully implemented as a multivariate analysis requires care in ensuring that the missing data is distributed randomly (De Vaus, 2002, p. 67).

3.8.4. Transforming the questionnaire data into choice data

The spreadsheet containing the SPSS-coded questionnaire was imported into the R software (R Development Core Team, 2019) and converted into a dataset useful for choice analysis using the *support.CES* package by Aizaki (2015). The data was transformed into a long format whereby each respondent had 12 entries representing the four choice sets with three alternatives. As a result, this new dataset had 7,788 entries

A strata variable was created to identify each combination of respondent and question. A new variable called RES was created, which served as the dependent variable used to indicate choice among the alternatives in the choice set. RES is a logical variable that is set to TRUE (or 1) when the alternative is selected and FALSE (or 0) when the alternative is not selected. ASC, the variable representing the alternative specific constant, was also created. This ASC variable captures the mean of the error term for the utility of an alternative in a choice model and is used in conditional and mixed logit models. The alternative invariant or alternative specific regressors vary between the individual and the alternative. For example, prices for the products vary for each product, and individuals may also pay different prices.

3.9. Empirical Analysis Hypothesis and Methods

3.9.1. Hypothesis

The following hypotheses are tested through the DCE analysis as contained in Section 5.2:

> H_0^1*: Householders would not prefer to dwell in homes within clean, quiet residential estates that use solar PV for backup electricity and are not willing to pay for this*
>
> H_0^2*: Individual characteristics have no effect on the preferences outlined in* H_0^1
>
> H_0^3*: Participants are not interested in participating in energy trading within a community setting.*

H_0^1 addresses the preferences and willingness of respondents to dwell in a home within clean, quiet residential estates that use solar PV for backup. Rejection of this hypothesis suggests that individuals might be motivated to dwell in homes within clean, quiet residential estates that use cleaner alternatives to generators, in this case, solar PV, for backup electricity and are willing to pay for this.

H_0^2 addresses the role of individuals characteristics on the preferences outlined in H_0^1. The main thrust of this hypothesis is to test if individual characteristics have any effect on the preferences outlined in H_0^1. Rejection of this hypothesis would show that preferences to dwell in homes within such clean and quiet homes are heterogenous and not the same among all respondents.

H_0^3 addresses preferences among respondents to participate in energy trading: The rejection of this hypotheses implies respondents are interested in participating in P2P energy trading.

3.9.2. Modelling approach

The analysis commences with a descriptive analysis of respondent characteristics. This includes a summary of demographic data collected. Relevant cross-tabulations of some responses to questions across the sample population also provide contextual information about study participants. Though the literature outlines different ways to analyse DCE data, it is advised to start with a simple Multinomial Logit Model (MNL), which assumes the independence of irrelevant alternatives (IIA) and then gradually introduce other model specifications (Aizaki, Nakatani and Sato, 2014; Hensher, Rose and Greene, 2015). This IIA restriction of the MNL specifies that the odds of the probability of choosing one class (set of alternatives) over another are independent of the broader set of alternatives in the choice set. As this assumption is unrealistic in practice, this study primarily employs choice models that relax IIA and other assumptions of the MNL and allow the model coefficients to vary over individuals by including stochastic components.

Specifically, the models employed to analyse the choice data generated in this study are the Mixed Logit Model (MXL) and the Latent Class Logit (LCL) Models described in sub-sections 3.9.3 and 3.9.4. The use of these models allows for robust investigation of preferences and allows for analysis of heterogeneity in the data (Franke and Nadler, 2019). The MXL and LCL are used primarily because they both overcome shortcomings of the MNL, as outlined above. The MXL has modelling benefits in that it exhibits neither the IIA property nor the restrictive substitution patterns of the MNL model (Wittink, 2011). Furthermore, even though the MXL is fully parametric, it is an information-rich model that can provide a large range to specify the individual and unobserved heterogeneity (Hensher, Rose and Greene, 2015).

The LCL is used to further examine the degree of heterogeneity among observations in the DCE. The underlying theory of the LCL model presumes that individual choice behaviour depends on the observable attributes and on latent heterogeneity that varies with the unobserved factors (Hensher, Rose and Greene, 2005). Given that the choice data in this study is in a panel or repeated form, the use of both models is also justified as the LCL also allows the harvesting of a rich variety of information on behaviour from a panel or repeated measures data set (Wittink, 2011).

Comparisons of both models in the literature reveal the benefits of using both models. For example, Greene and Hensher (2003). compared the MXL model and the LCL model with an application in the transport sector. They concluded neither of the models is unambiguously preferred to the other. The LCL model has the advantage that it is a semi-parametric specification, with the benefit of freeing the researcher from possibly strong or unwarranted distributional assumptions about individual heterogeneity (Greene and Hensher, 2013; Champ, Boyle and Brown, 2017). From a practitioner's perspective, a comparison of both models by parameters Sagebiel (2017). reveals that the MXL is more complex, and the estimation process demands computational time and deep model understanding. Sagebiel also states that the flexibility of the MXL can prove problematic in identifying the correct specification, unlike the LCL, where the selection of the optimal number of classes is relatively straightforward. The MXL and LCL models are described in detail in the next section. Results are subjected to relevant tests to ensure robustness, including the traditional measures of fit, predictions and statistical tests. The analysis is carried out using Stata 16 (Stata Press, 2019) using Stata 16's inbuilt Choice Modelling functionality and user-written command *lclogit2* (Yoo, 2019).

3.9.3. Mixed Logit (MXL) model

The MXL model (also known as the Random Parameters Logit - RPL Model or the Mixed/Heterogenous MNL model) is a very flexible model that can approximate any RUT (McFadden and Train, 2000). MXL assumes that preferences vary across individuals but not across the choices of the same respondent. It bypasses the limitations of the multinomial logit model by allowing for random taste variation, unrestricted patterns and correlation in unobserved factors over time. To relax the IIA assumption and allow examination of unobserved preference heterogeneity, the parameters in the Mixed Logit model can vary randomly among participants.

When estimating the MXL model, the random parameters need to be specified, and the effect that a specified parameter will have on the chosen alternative will vary across the respondents in the sample. The MXL model applies a clustered specification to allow for repeated choices for every respondent. Therefore, each respondent has multiple responses in the dataset used for analysis. The model produces random parameter coefficients for both the regressor and its standard deviation. The interpretation of the coefficients is such that an increase in the independent variable will mean that respondents are more or less likely to choose the alternative. The standard deviation of a regressor allows the determination of the heterogeneity across individuals concerning the effect of the independent variable on the selected alternative. The MXL probabilities are the integrals of the logit probabilities over a density of parameters.

$$P_{in} = \int L_{in}(\beta) f(\beta)\, d\beta, \qquad \text{.... (1)}$$

- Where $L_{in}$is the logit probability evaluated at the parameters β
- And $f(\beta)$ is a density function.

If the utility is linear in β, then;

$$V_{in}(\beta) = B' x_{in} \qquad \text{.... (2)}$$

Hence the MXL probability then takes its usual form

$$p_{in} = \int \left[\frac{e^{\beta' x_{in}}}{\Sigma_j e^{\beta' x_{jn}}} \right] f(\beta)\, dB \qquad \text{.... (3)}$$

The MXL model used is jointly estimated on four panels of stated choice datasets that correspond to each of the four times the respondents' choices were evaluated. The model is a mixed logit model that allows accounting for panel correlation among choices from the same respondent in the choice dataset (Noel *et al.*, 2019). The joint estimation of the model allows controlling for scale differences between the four datasets and, therefore, also for direct comparison of individual preferences across the four periods of evaluation

In the discrete choice model, respondents choose one of the three options offered in the choice experiment (two can be categorized as "clean and quiet" and one status quo option). Using the respondents who preferred the status quo as the opt-out alternative and letting the respondents' choice depend on the choice attributes in the experiment, the utility is described by the function

$$Ut_{ins} = \theta(ASC_{it} + \beta t_n' x_{ins} + \mu t_{in} + \varepsilon t_{ins}). \quad \text{.... (4)}$$

$$Ut_{0ns} = \theta(\mu t_{0n} + \varepsilon t_{0ns}).$$

Where;

- Ut_{ins} is the utility that each respondent n from time t associates to alternative i, in the choice scenario s
- x_{ins} is the observed attribute vector and;
- β_n is a vector of individual-specific taste coefficients with a mixing distribution of $f(\beta|\theta)$; and θ denotes the parameters of this distribution (the mean and covariance of β);
- ASC_{it} are the alternative specific constants.
- μt_{in} are error components, normally distributed (with mean zero and standard deviation σt_{in} across individuals.
- εt_{ins} denotes the unobserved error term, which is assumed to be Gumbel-distributed.

The choice probabilities are now given as

$$P_{in} = \int L_{in}(\beta) f(\beta|\theta)\, d\beta \quad \text{..... (5)}$$

Since, L_{in} is the logit probability, which is given by the expression,

$$L_{in}(\beta) = \frac{e^{\beta' x_{in}}}{\sum_{j=1}^{j} e^{\beta' x_{in}}}, \quad \text{..... (6)}$$

Hence the choice probability can be fully expressed as;

$$P_{in} = \int \frac{e^{B' x_{in}}}{\sum_{j=1}^{j} e^{B' x_{in}}} (\beta) f(\beta|\theta)\, d\beta \qquad \text{.... (7)}$$

The probabilities are approximated through simulation for any given value of the parameters in the model. The log-likelihood is maximised using the maximum simulated likelihood estimator methods as described by Train (2003) as follows;

$$SLL = \sum_{n=1}^{N} \sum_{j=1}^{J} d_{jn} \ln P_{jn} \qquad \text{..... (8)}$$

In the case of repeated choices, a sequence of alternatives can be considered, with one for each time period where $i = [i_1, \dots, i_T]$.

The probability that the decision-maker would make a sequence of choices is given by the product of the logit formula conditional on β (Wittink, 2011).

$$L_{in}(\beta) = \prod_{t=1}^{T} \left[\frac{e^{\beta' x_{in}}}{\sum_{j=1}^{j} e^{\beta' x_{in}}} \right] \qquad \text{..... (9)}$$

The unconditional probability is the integral of this product's overall values of β and is given by

$$P_{in} = \int L_{in}(\beta) f(\beta|\theta)\, d\beta \qquad \text{..... (10)}$$

The mixing distribution of parameters θ and the vector β in the MXL model can be specified with a continuous parametric distribution like the log-normal, normal or triangular distributions (McFadden and Train, 2000; Tu, Abildtrup and Garcia, 2016). Similar to the case of one choice period, the probability is simulated using the maximum simulated likelihood estimator.

3.9.4. Latent Class Logit (LCL) Model

Several studies have applied the LCL model to examine the degree of heterogeneity among observations in DCEs, (Boxall and Adamowicz, 2002; Shen and Saijo, 2009;

Sagebiel and Rommel, 2014; Van Rijnsoever, Van Mossel and Broecks, 2015; Rommel, Sagebiel and Müller, 2016; Sagebiel, 2017; Matyas, 2020; Zha *et al.*, 2020). In the LCL model, preference heterogeneity arises from varying classes, with each class having its own parameters (Sagebiel, 2017). In consistency with (Wittink, 2011), mixed logit (MXL) choice probability can be specified as:

$$p_{in} = \int \left[\frac{e^{\beta' x_{in}}}{\Sigma_j e^{\beta' x_{jn}}}\right] f(\beta)\, dB \qquad \text{.... (1)}$$

According to (McFadden and Train, 2000), the LCL is simply when the mixing distribution in the MXL model described above has finite support. This means $f(\beta)$ is specified as discrete instead of being continuous, with β having a finite set of distinct values (Wittink, 2011). In the LCL, β assumes M possible values which are labelled as $b_1, \ldots, b_M$ with probability s_m that $\beta = b_M$.

The MXL model is characterized by its capacity to accommodate unobserved preference heterogeneity as a continuous function of the utility parameters, while the LCL estimates preference heterogeneity with respect to differentiated classes with specific parameters (Sagebiel, 2017). The LCL model relaxes the requirements that the researcher make specific assumptions about the continuous distribution of parameters across each decision-maker (Wittink, 2011)

To examine the degree of heterogeneity among individuals, this study employs the latent class model, which assumes that the population consists of a number of latent classes S, which captures the unobserved heterogeneity among individuals by estimating a different parameter vector in the corresponding utility function.

This could yield the probability in an individual class, s (Zha et al., 2020).

$$P_{iq|s} = \frac{exp(\mu_s \beta_s' X_{jq})}{\sum_{j=1}^{j} \exp(\mu_s \beta_s' X_{jq})} \qquad \text{..... (2)}$$

X in the relationship defined in Eq. (2) is a vector of variables that is related to alternative attributes. Drawing from Boxall and Adamowicz (2002), and Shen and Saijo, (2009), the probability of individual q being in class S (H_{qs}) can be expressed as:

$$H_{qs} = \frac{exp(\alpha\lambda_s' Z_q)}{\sum_{s=1}^{S} \exp(\alpha\lambda_s' Z_q)} \qquad ..... (3)$$

In this case, α is a scale parameter, which is always set to 0; λ_s' is the parameter vectors in class s, and Z_q represents the individual characteristics (e.g. age, sex, education, awareness, income). When conditional choice Eq. (2) is combined with Eq. (3), the unconditional probability of respondent q choosing i is

$$P_{iq|s} = \sum_{s=1}^{S} P_{iq|s} \times H_{qs} = \sum_{s=1}^{S} \left[\frac{exp(\mu_s \beta_s' X_{jq})}{\sum_{j=1}^{j} \exp(\mu_s \beta_s' X_{jq})} \right] \times \left[\frac{exp(\alpha\lambda_s' Z_q)}{\sum_{s=1}^{S} \exp(\alpha\lambda_s' Z_q)} \right] \qquad ..... (4)$$

In a LCL model, μ_s and α are set at 1, and it is possible to estimate P_{iq} from the choice experiment (Boxall and Adamowicz, 2002). The maximum likelihood method can be applied to estimate parameter vectors β_s' and λ_s'. Then, it is possible to test the effect of the variables on respondents' choices (Zha et al., 2020).

To estimate a LCL model, the class S should be known (Zha et al., 2020). There are no foundational theories on the number of classes to be chosen by the investigator (Sagebiel, 2017). Common Measures of fit, like the AIC and BIC, are used to identify the optimal number of classes. The measures are defined as follows:

$$AIC = -2(\log L_S^* - K_s) \qquad ..... (5)$$

$$BIC = -\log L_S^* + (K_s \log N) / 2 \qquad ..... (6)$$

Here, N is the size of the sample, and the number of parameters of s class is K_s and $\log L_S^*$ refers to the log-likelihood of the model.

3.9.5. Reliability and Validity Issues

Reliability and validity are very important criteria that can be used to establish and assess the quality of research done using quantitative methods. Reliability refers to the degree of reproducibility of the results, while validity refers to the degree to which the method is truly measuring what the researcher intended it to (Freeman, 2003). Reliable survey data is one that ensures dependable and consistent responses from participants. To ensure the reliability of the data collected in this study, internal consistency methods are employed. Specifically, the Cronbach alpha test of reliability is used to check for consistency in the DCE questions with multiple response categories. The Cronbach alpha test is used as it is the most suitable and provides the most thorough analysis of patterns of internal consistency (De Vaus, 2002, p. 21). This is also more suitable for alternative methods such as the test-retest method, parallel forms method, or split-half correlations. A Cronbach alpha of 0.7 is normally considered to indicate a reliable set of items. The DCE questions in this study had an alpha of 0.71, as seen in Table 3-3 below demonstrating reliability and internal consistency of the responses to the questions[28]. The section of the questionnaire with the highest alpha was the section where respondents were asked about their interest in energy trading which had an alpha of 0.92 suggesting relatively high consistency in the responses of participants.

Table 3-3: Questionnaire Reliability Estimates

DCE Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Questions (N)
.712	.710	4

Section B - Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Questions (N)
.918	.920	10

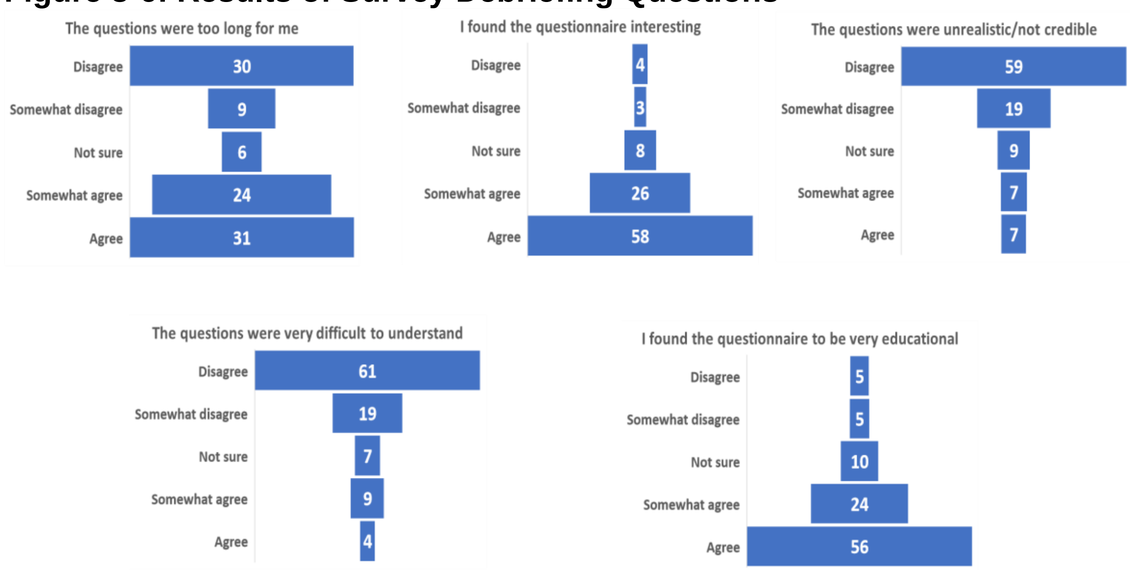
Validity in social survey data means ensuring that the data collected adequately measures the concept(s) that an analyst is trying to measure. A valid measure is one that is “on target”, as it would always “hit the bull’s eye” (Trochim, 2000, cited in De Vaus, 2002). Validity in quantitative survey data is typically measured using Internal and external validity methods. Whilst De Vaus (2002) simply classifies validity as comprising criterion, construct, content, convergent and discriminant methods, Rakotonarivo et al. (2016) further classify these into external and internal validity.

[28] Furthermore, the Kuder-Richardson reliability coefficient the same as the Cronbach alpha test is also employed for dichotomous responses with simple yes/no categories.

Rakotonarivo et al. (2016) classify external validity as consisting of criterion and convergent methods, whilst internal validity comprises theoretical and content validity.

Criterion Validity compares a question’s responses to those from an established measure, with a high correlation between both responses demonstrating validity in the new measure. Some challenges with this method involve the inherent assumption that the criterion measured is valid and the lack of a well-established criterion against which to check the new measure. Construct validity deals with how the measures behave, in line with a theoretical understanding of the concepts they were designed to measure. Convergent and discriminant validity are subtypes of construct validity that rely on having numerous measures of a concept instead of a single measure. Content validity refers to checking the extent to which the measure captures various elements of the concept being named. This form of validity includes the use of debriefing techniques such as qualitative questions, interviews or focus groups to assess both the axioms and respondents’ perception, comprehension and responses to the survey. This expression of their comprehension can be in a stated or rated form. To address this, the survey included debriefing questions as outlined in Section 3.7.4. Findings from the debriefing questions in the survey (see Section F of Appendix A9.) are presented in Figure 3-6 below.

Figure 3-6: Results of Survey Debriefing Questions



Source: Field survey (Section F)

In response to the question on the length of the survey, more than half of the respondents (55 per cent) felt the questionnaire was too long for them, with about 39 per cent holding the view that the questionnaire was not too long for them. There was widespread interest in the questionnaire among respondents, as about 84 per cent of respondents found the questionnaire to be interesting. Similarly, a high proportion of the respondents found the questionnaire to be realistic and credible, with 78 per cent of respondents disagreeing or somewhat disagreeing with the statement "*the questions were unrealistic/ not credible*". The respondents also broadly comprehended the responses to the questionnaire, as the majority of respondents (80 per cent) did not find the questionnaire difficult to understand. Finally, the questionnaire was also seen to be very informative for respondents, with 80 per cent of respondents finding the questionnaire to be very educational. These findings give some comfort regarding the respondents' overall comprehension of the questionnaire.

3.10. Survey Ethical considerations

The survey received ethical approval by UCL's Research Ethics Committee (Approval Number: Z6364106/2019/05/114 social research). Participants were allowed to read an information sheet written in plain English outlining study details before partaking in the survey. They were also informed about the voluntary nature of participation, assured confidentiality of their responses and the steps to protect their data in accordance with relevant data protection legislation. Voluntary consent was sought, and interested participants completed a signed informed consent form. The participants were allowed to withdraw from the study at any time without giving a reason. The participant information sheet and informed consent form are provided in Appendix A7 and A8.

3.11. Conclusion

This chapter has outlined the mixed methods research design adopted in this study to answer the research questions. The chapter outlined the pragmatic research paradigm employed and a detailed explanation of the qualitative and quantitative methods employed. It discussed the main analysis phases, including thematic analysis used in the qualitative phase and discrete choice modelling of preferences employed in the quantitative phase.

4. CHAPTER 4: BACKUP ENERGY ATTRIBUTES IN MULTI-OCCUPANT HOMES IN A NIGERIAN URBAN CITY: AN EXPLORATORY INVESTIGATION

Chapter Overview

The previous chapters have discussed the study rationale, questions, literature review and methods. The literature review in Section 2.1.3 demonstrated how previous work on the preferences of individuals to adopt solar PV had given little attention to the nuances of solar PV adoption as a form of backup electricity among end-users. This chapter presents results from the qualitative analysis highlighting how it influences the design of the subsequent quantitative analysis.

4.1. Introduction

Energy plays a crucial role in the functioning of residential households. It is used to power appliances, lighting, and other essential household functions. As such, it is important to consider the various attributes of energy in order to make informed decisions about energy usage in the home. This chapter explores some of the important attributes to consider for households regarding backup energy provision in residential households. By understanding these attributes, households can work towards more sustainable and efficient energy usage and contribute to a cleaner and more environmentally friendly future.

This chapter, which is mainly exploratory in nature, showcases insights from discussions with real estate agents as described in Chapter 2. The main reason why the interviews were sought with the real estate agents was to gain insights into backup energy usage in residential homes. This clarity was important given the way in which the transition to renewable energy is typically framed from a developed country perspective. That is, in the developed world, the emphasis is on the transition to cleaner energy options, mostly for the grid. In the case of home systems, the emphasis is for individuals to save on energy costs (Child et al., 2019; Lowitzsch, Hoicka and van Tulder, 2020). For industry, the focus is to improve their sustainability profile ((Ikäheimo et al., 2018; Kakoulaki et al., 2021). However, in places where grid-based electricity supply is unreliable and largely unstable, it might be the case that framing might not exactly work.

Perhaps, this existing way of framing the transition to renewable energy might not hold in such contexts, as people might prefer to get electricity from whatever means they can easily get (Olanrewaju et al., 2019; Adenle, 2020). To make the transition to renewable energy among residential users of energy in these contexts, another component, in addition to technical, economic, and social factors can be the way renewable energy options are presented to people. In essence, to frame the transition as something that provides benefits to the individuals other than costs, technical efficiency or improves social interaction. Rather this can be framed as something that provides value to the local environment in addition to all these aforementioned benefits (Sundt and Rehdanz, 2015c; Ulsrud *et al.*, 2015; Brummer, 2018; Carley and Konisky, 2020; Lee *et al.*, 2020). This value is specifically referring to local environmental benefits resulting from clean air and reduced noise pollution.

This study examines preferences for dwelling in homes in clean and quiet residential estates in Nigeria. In determining the scope of the study and to properly understand the local context, it was important to initially outline specific attributes that residents in Nigeria look out for when deciding on a new home. As such, the exploratory qualitative study was conducted as outlined in section 3.4. This phase was also important in narrowing the focus of the research. Specifically, semi-structured interviews were conducted with various real estate agents in Nigeria. This phase of the research investigated the perceptions and experiences of real estate agents regarding backup energy usage in blocks of flats and rental buildings. These interviews also served to understand the manner in which backup energy is framed when residents are discussing the decision to rent a home. In addition to this, an interview was also conducted with the representative of a solar energy company in Nigeria to understand their experience of the adoption of solar PV installations in blocks of flats and urban multi-occupant buildings in Nigeria. The rest of this chapter contains the chapter objectives, results and a conclusion.

4.2. Chapter Objectives

The specific objectives of this chapter are to:

- Identify attributes that residents look out for when deciding on a new home.
- Investigate perceptions and experiences of real estate agents regarding their backup energy provision in residential estates.

4.3. Results

From the expert interviews, five main themes emerged regarding the attributes that residents seek when renting a home, as summarized below.

- **Home Ownership Aspiration**: Home ownership is one of the aspirations of Nigerians and can be categorised based on three socioeconomic categories.
- **Home Attributes**: Two key attributes that residents seek when deciding on a new home are electricity and water availability. Despite the understanding that the electricity supply is not constant, potential clients still ask about the electricity availability when enquiring about a new home.
- **Backup Energy Provision**: Backup electricity is usually provided by residents and not landlords in rental buildings
- **Residents and not landlords primarily drive solar energy adoption**.
- **Interest in living in clean and quiet areas**: Middle and high-income residents value living in clean and quiet areas, while low-income households might not prioritise this. Some high-income households might also be willing to pay more to have reliable, clean and quiet backup electricity.

4.3.1. Home Ownership Aspiration

The findings from the exploratory interviews exemplified the notion that home ownership is one of the aspirations of Nigerians. Furthermore, there are various reasons why people want to own a home. This homeownership aspiration can be categorised based on three socioeconomic categories. In the lower socioeconomic strata of society, such people want to own a home to feel emancipated from the pressures of dealing with landlords[29]. They prefer to live in such homes, even if there are few amenities and facilities, or in ramshackle high-density neighbourhoods in semi-urban Ibadan. Such people are simply pleased to have a home they can call their own and might not be bothered by noise and air pollution.

Comment	**Respondent**
"If you study Ibadan very well, those low-income earners… they have houses in Ibadan, they are the ones you see in different settlements, they love to own their house…. It might not be something fantastic, but they want to have a roof over them… They just manage something. They might not be in the (town) centre. They will just buy land and then gradually start building."	Agent Chike

The next category of people within the middle-income strata of society wants to own homes that make them comfortable. Such people might consider buying homes or purchasing land to build their homes in upmarket locations. They will want their homes to be comfortable and have good facilities and amenities.

At the other end of the spectrum, the interviews revealed that individuals in the high-income strata want to own a status home as a showcase and symbol of their wealth[30]. Such palatial homes are usually in high-end estates and have top-notch facilities and amenities. The interviews revealed that such people would prefer to live in clean, less polluted neighbourhoods. The discussions also indicated a preference for dwelling in areas without noisy and air-polluting generators. Hence, it was appropriate for the choice experiment to present choices based on home ownership instead of renting because of Nigerians' aspirations regarding home ownership. Furthermore, as these

[29] In Yoruba, one of the local dialects in Nigeria, and the prevalent dialect in South West Nigeria, this is commonly dubbed as "*ki onile ma le mi*" which is translated in English as "*so that the Landlord doesn't keep disturbing me".*

[30] Which is synonymous with conspicuous consumption as depicted by Veblen to describe ostentatious consumption of expensive goods and services as a public display of wealth (Veblen, 2007).

exploratory interviews revealed that those in high-density neighbourhoods might not prioritize the clean and quiet benefits, the quantitative phase primarily focused on residents in residential estates.

Comments	**Respondent**
"Because it is given that the high-income areas (neighbourhoods) are quiet as well as the middle-density areas… by asking for low-density areas, such people are already expressing their desire to live in more quiet neighbourhoods without necessarily verbalising this when making their decisions."	Agent Deji
Some of them mention that they want quiet places like Jericho, which is serene and there is light (utility/publicly provided electricity), there is less pollution through generators	Agent Bayo

Home Attributes

The interviews revealed that various attributes that residents seek when looking for a new home include location, security, accessibility, age of the building, types of amenities, facilities and finishing in the house. Other attributes include price, electricity and water availability in the house. However, these last two attributes of electricity and water availability appear to be key attributes that residents seek.

Comments	**Respondent**
"Basically clients… require electricity and water. Anybody looking for a house must be sure there is electricity and water supply. Those are the two basic ones that people always ask for no matter where it is."	Agent Chike

Focusing on electricity supply, which is essential in this study, even though it emerged as a key attribute that residents ask for, most estate agents recognise that electricity supply is not constant in the city and the country. They also pointed out that despite this common understanding, their clients still request to live in places where there is relatively stable electricity availability. The estate agents indicated that they cautiously advise residential clients on locations with fairly regular electricity supply. This suggests that even though there is a general acceptance that grid-based electricity is not constant, there is interest in living in places where the electricity supply is reliable. This interest in electricity reliability also formed the basis for exploring the role of electricity reliability in the P2P energy trading study, as outlined in Section 6.4.1.2.

Comments	**Respondent**
"They (clients) want a good area where the light is stable. But generally, light is not stable anywhere."	Agent Enitan
"When they (clients) ask for the power availability, most times, we tell them (about it), and most times we tell them that we are not NEPA.[31]"	Agent Bayo

Furthermore, the estate agents revealed that some residents are also aware of parts of the city with relatively stable electricity supply. They make specific requests to the agents to get them homes in such places. Some of the locations they highlighted include Jericho estate, Oluyole estate, Elebu estate, Ring Road and the GRAs (Government Reserved Areas)[32]. The respondents also indicated that high-income households tend to prefer living in these GRAs.

[31] This refers to the former state-owned national utility and is a term synonymous with erratic grid electricity supply in Nigeria.

[32] The respondent explained that "*the GRAs are places where government will build and allocate. Originally these were to be built and given to the civil servants (which were the middle-class people then) before other individuals started coming in".*

Comments	Respondent
“Some of them even know (places where there’s relatively stable electricity supply); they tell you this is the one (place) they want.”	Agent Bayo

It was also evident from the interviews that residents were typically keen to find out about the state of the electricity connection in the flats, including ensuring that there was no previous debt still accruing on the meter by previous respondents.

Comments	Respondent
“They want to be sure that it is free (no prior debt on the meter by previous occupants) and whatever the NEPA (National Electricity Power Authority) brings is what they pay for.”	Agent Chike

4.3.2. Backup Energy Provision

Another finding from the interviews was that presently backup electricity is usually provided by tenants and not landlords. Landlords are typically only responsible for providing the proper utility electricity connection and wiring. Tenants use their backup systems, such as diesel or petrol generators, inverters and batteries, or solar systems. There are instances where landlords provide backup energy; however, this is primarily the case in serviced apartments usually taken up by people “in transit” in the city, such as expatriates or people who come for short-term work. These serviced apartments are a typical instance where high-income earners are renting. In these serviced apartments, the expectation is that the landlords provide backup electricity. A service charge is typically taken in addition to the rent to offset the costs of providing backup electricity.

Drawing on this, since this research focused on the preferences of homeowners, the choice experiment did not present the choice of homes in such serviced apartments. Instead, respondents were presented with the choice of living in housing estates where residents provide backup energy by themselves. Whilst the DCE survey did not ask questions on dwelling ownership in hindsight, the collection of this data would have been an important validity check to determine the appropriateness of focusing on estates with primarily home ownership. Such data would have also been useful in identifying any differences in preferences between homeowners and renters.

Comments	**Respondent**
"Some tenants ask for backup energy provision; however, the tenants are mostly responsible for providing their own backup energy. However, if they want to install their backup options like solar, then they must inform the landlords about it."	Agent Bayo
"Certainly, it (backup energy) is always through generators, and they (residents) bring in their generators. Very few properties have (existing) generators in place for residential multi-tenanted homes."	Agent Deji
"Majority of the people providing backup electricity are the tenants themselves"	Agent Akin

Another finding on backup energy provision was adaptations to energy usage in contexts where publicly available electricity supply is erratic. This is particularly important because electricity is not an end, but a means to an end. In this case, this is to meet thermal comfort needs etc.

Comments	Respondent
“The only thing it (backup solar PV) does not power is the air conditioners because we have all the air conditioners in the rooms, and they cannot put all the air conditioners on. It will just drain the batteries. It powers the lights... but is not used to pump water.”	Agent Akin

4.3.3. Residents and not landlords primarily drive solar energy adoption.

The real estate agents also expressed that landlords might not be keen on providing clean and quiet backup electricity, such as through solar home systems. A reason put forward was the perception that the financial benefits landlords might derive from receiving higher rents might not be “worth the stress” of deploying such systems. Another likely reason might be these systems' perception of relatively high initial costs and challenges with accessing credit. Another reason why the landlords might not be keen on providing backup electricity through clean sources such as solar might be the split incentive. This split incentive arises whereby landlords might not reap the direct benefits of using the technology.

Comments	Respondent
“Actually, this issue of cleaner and backup energy, people come in with their own. That is what we have experienced so far. Because no landlord is willing to go into that, it is quite enormous (costly) for them to go into that.”	Agent Deji
“The initial capital outlay is much, and if you look at whatever higher income the landlord hopes to get, the difference is not worth it.”	Agent Deji

Furthermore, based on the discussions with the solar company, it was evident that most homeowners or residents install solar PV in their homes rather than landlords doing so for tenants' use. When solar PV was installed in rented apartments, it was purchased mainly by tenants themselves rather than the landlords installing the backup solar PV for tenants. The direct beneficiary of the system was seen to be the essential decision-makers regarding adopting solar PV.

Comments	**Respondent**
“It is very rare (landlords providing solar PV) … but we rarely have landlords coming to get it (solar PV) for their tenants; they most times get it for themselves… It’s mostly the people renting homes themselves… And the landlord’s installing it for their (own) houses.”	Agent Ige

Other reasons put forward for the lack of interest by landlords in providing backup electricity through clean energy sources like solar include a lack of trust in the quality of the solar systems. As outlined earlier, landlords do not typically provide backup electricity for their tenants. Respondents provided some suggestions that might make it attractive for landlords to provide clean and quiet backup electricity as an additional service to the tenant. These include reductions in costs of solar systems, alongside the availability of experienced installers, availability of after-sales services, product standardisation, and other incentives for uptake.

Comment	**Respondent**
“This will be very attractive to the clients (landlords), and this will put them in a better position to provide backup energy as an additional service to the rent. As the way things are, it is not exactly attractive for tenants and even landlords themselves”	Agent Enitan

4.3.4. Living in Clean and Quiet Areas

The interviews also revealed that middle and high-income residents value living in clean and quiet areas. These high-income households might also be willing to pay more to have reliable, clean and quiet backup electricity. For those renting, they indicated that they might be prepared to pay service charges in addition to their rent. In some instances, agents noted that clients often specifically asked for "quiet" environments, which also meant they preferred environments without noise pollution, such as generators. This finding informed the design of the DCE, which examined homeowners' preferences to dwell in estates where backup generation is from a clean and quiet source such as solar PV instead of generators.

Comments	**Respondent**
"Most clients are willing to pay a little above market value in terms of rental if they can have an environment that is less polluting and has an uninterrupted energy supply."	Agent Gbenga
"Some clients ask for a quiet environment."	Agent Femi

During an interview with a real estate agent, it was discovered that the agent was using solar energy for backup energy both at home and in the office. This presented a unique opportunity to interview the respondent as a solar energy adopter rather than solely as a real estate agent. Hence, I took advantage and explored some of the factors that influenced uptake. The main drivers of this respondent's decision to use solar panels were the ability to have a clean, uninterrupted power supply with no noise pollution and minimum maintenance. This finding further highlighted the interest in having the clean and quiet benefits that solar energy provides in addition to supply reliability.

4.4. Conclusion

This chapter outlined findings from exploratory qualitative interviews conducted to investigate preferences for backup energy among residents in a Nigerian city and shape the subsequent quantitative phase's design. Results reveal that tenants and not landlords primarily provide backup power in Nigeria for reasons including the split incentive problem and a lack of trust in cleaner backup energy sources like solar. It also revealed that middle-income and high-income residents valued living in clean and quiet areas and indicated that they might be interested in paying to enjoy these benefits.

The findings from these expert interviews shaped the subsequent PhD work, notably the choice experiment design. The exploratory phase of the study aided in narrowing down the scope of this study and identifying the attributes of homes to explore further using the choice experiment. For example, before embarking on the exploratory study, there was an attempt to focus the choice experiment on multi-occupant rental homes where landlords provide backup energy. However, based on the findings, backup power in Nigeria is mainly supplied by residents themselves and not by landlords. Hence the choice experiment presented buying a home in a new estate rather than a rented multi-occupant building.

Additionally, the interview findings provided some nuance to the relative importance of certain attributes. For example, the noise and air pollution attributes were seen to be an important consideration, particularly for middle to upper-income households. This finding that such residents value living in clean and quiet areas informed the decision to include a pollution attribute in the discrete choice experiment.

In conclusion, energy plays a vital role in residential households, given that it is essential for powering appliances, lighting, and other household functions. There are several considerations that are important to consider when it comes to residential households deciding on a new home. This chapter has shed light on some of the key considerations, such as the fact that backup energy provision is mainly the responsibility of the tenants and not the landlords. By taking these into consideration, relevant stakeholders can make informed decisions about the use of backup energy in residential households in Nigeria. The interviews also provided a platform for real estate agents to share their experiences and perspectives on backup energy usage, which can help to inform the development of new strategies and approaches to clean backup energy supply.

5. CHAPTER 5: USING A DISCRETE CHOICE EXPERIMENT TO VALUE PREFERENCES FOR CLEAN AND QUIET ATTRIBUTES OF BACKUP SOLAR PV IN NIGERIA

Chapter Overview

This chapter presents details of the results of the analysis conducted on the discrete choice experiment data. Individual preferences for attributes of solar energy from the DCE data are analysed using econometric models for discrete choice data, including the multinomial logit model, mix-logit model, and latent class analysis. This chapter also presents WTP estimation of preferences for solar energy as a form of backup electricity. Finally, the results from the models are subjected to relevant tests to ensure robustness. A version of this chapter has been prepared for submission to the Energy Reports Journal.

5.1. Introduction

As established in Section 1.1, despite the enormous energy potential within Nigeria, the largest economy in Africa and the most populous African country[33], the country is still beset with challenges in providing clean and sustainable electricity to its citizens. The country's installed grid power is estimated at 30 Watts per person, compared to the global average of about 900 Watts per person (IFC, 2019). Erratic grid supply, which is commonplace in the country – about 30 outages a month (Ramachandran *et al.*, 2019) – has led to reliance on self-generation through backup (diesel and petrol-fired) generators to meet electricity demand. Running these generators is estimated to cost 6 to 10 times more than paying for grid-supplied electricity (Radwan and Pellegrini, 2010). The Rural Electrification Agency (2017)[34] estimated that Nigerians spend $14 billion annually on inefficient generation, primarily through these

[33] With a population of over 200 million people and estimated GDP of US$477.1 billion (constant 2010 US$) (World Bank, 2020b)

[34] In conjunction with the World Bank and Rocky Mountain Institute (RMI)

generators. These generators also contribute to global climate change through the associated carbon emissions[35].

However, an often-overlooked aspect is the *local* danger and nuisance that these generators cause. There are fire and safety risks, noise and air pollution, and consequent health risks from inhaling exhaust fumes (Iyogun, Lateef and Ana, 2018; IFC, 2019). In contrast, solar photovoltaic (PV) backup systems offer reliability and clean, serene, and safe local environments, so long as local generator use is curtailed. Homeowners using solar energy suffer negative externalities as their neighbours can still use polluting generators (Oseni, 2016). The ‘clean-quiet-safe’ benefits that solar-PV could offer a local environment can only accrue if that local community excludes polluting backup generators.

5.2. Link to Research Objectives

Substantively, this chapter makes three distinctive contributions. Although previous studies have examined solar-PV for generating cleaner electricity, until now, no identified studies have examined interest in, or WTP for, the *local* environmental and safety benefits that solar-PV could offer purchasers of homes on residential estates that exclude polluting backup generators in Nigeria. In this case, the local pollution and risks that solar-PV could mitigate are produced by *backup* electricity generators. Consequently, this study is also the first known to examine the potential of solar PV as a form of *backup* electricity in Nigeria and the WTP for specific attributes of solar PV. Another benefit of widespread local adoption of solar PV systems is the potential for individuals to buy and sell excess electricity using emerging P2P energy trading technology; this paper also examines preferences for *energy trading* within a community setting.

As well as contributing to the literature on these substantive topics, this chapter also contributes *empirically* by examining these consumer preferences using DCEs within residential neighbourhoods in Ibadan, a Nigerian city. As outlined in Section 2.1.3, Grimm et al. (2017) called for more experimental studies examining the mechanisms

[35] Moss and Gleave (2014) estimate that generator use in Nigeria produces 29 million metric tons of CO2 annually.

behind the take-up behaviour of solar PV in developing countries, including households' WTP for electric energy and the role of credit constraints and information. This chapter addresses the need for more experimental studies in the RE field by using DCE to:

1) explore whether householders would prefer clean, quiet residential estates that use solar PV for backup electricity and are willing to pay for this[36],
2) analyse the influence of *individual* characteristics on these preferences,
3) examine preferences for energy trading within a community setting.

5.3. Results

5.3.1. Demographic and Summary statistics

The socioeconomic characteristics of the sample are provided in Table 5-1. The sample is slightly skewed towards men, as the male-female ratio is 59 per cent - 41 per cent, respectively, which is higher than the population figures for South-West Nigeria of 48 – 52 per cent[37]. The sample was primarily composed of respondents aged between 30-39 and those aged between 18-29, who collectively represented over half of the respondents (54.3 per cent). Married respondents constituted the larger share of the marital status of the sample (67 per cent) compared to a quarter of respondents that are single. This is higher than the share of married people in South-West West Nigeria (50.2 per cent).

Within the sample, the majority of households (79.4 per cent) live in households with three or more people sample (The south-west population has an average household size of 3.2), and most respondents reside within the Ibadan urban area (64.1 per cent) compared with 35.9 per cent in the Ibadan semi-urban area. The distributions of educational level and annual household income revealed that 90.6 per cent of the respondents had polytechnic, university or advanced degrees, and over a third (31.4 per cent) of the respondents had an annual household income between ₦100,000

[36] Solar PV was still boradly perceived as an expensive technology at the time this research was conceptualized
[37] Population statistics derived from (National Bureau of Statistics and World Bank, 2019)

(US$326) and ₦250,000 (US$815). This implies that most respondents are highly educated and earn within the average living wage for Nigerian households[38].

Table 5-1: Respondent socioeconomic characteristics (N = 649)

Variable	Description	Frequency	Percentage (%)	Population (%)
Household size	Households with 1 person	35	5.6	Average household size in urban areas (4.8)
	Households with 2 people	94	15	
	Households with 3 or more people	496	79.4	
	Average		2.75	3.20
Households with Children	Households living with children	382	63.1	
	Households living without children	223	36.9	
Gender	Male	371	59.2	47.9
	Female	256	40.8	52.1
Marital Status	Married	415	66.9	50.2
	Single	158	25.5	35.3
	Other Categories	47	7.6	4.85
Age	Mean age (interval data)		41	
	18- 29	161	26.9	
	30 – 39	164	27.4	
	40 – 49	114	19.1	
	50 – 59	77	12.9	
	60 -70	52	8.7	
	71 and above	30	5	
Urban: *Depicts if the Household lives in Ibadan Urban Area or the Ibadan Semi-Urban Area*	Ibadan semi-urban area	217	35.9	
	Ibadan urban area	387	64.1	
Household Monthly Income *(N)*	Average (interval data)		₦284,284.4	
	Less than ₦100,000	113	18.3	
	₦100,000 – < ₦250,000	194	31.4	
	₦250,000 – < ₦500,000	136	22	
	₦500,000 – < ₦750,000	48	7.8	
	₦750,000 – < ₦1million	39	6.3	
	₦1million or more	22	3.6	
	Prefer not to say	66	10.7	

[38] This is estimated at ₦203,040 (US$662) based on assumptions of 4.7 individuals per household (derived from The McKinsey Global Institute (2014, p. 3) earning an income of ₦43,200 (US$141) in 2018 (derived from Trading Economics (2020).

Occupation	Employers	27	4.3	
	Full time	181	28.8	
	Part-time	46	7.3	
	Self-employed	157	25	
	Retired	78	12.4	
Education of the household head	No formal education	9	1.4	
	Secondary, Primary or less	33	5.2	
	Tertiary	595	90.6	
	Others	12	1.8	

Table 5-2 presents some data on respondent responses to questions about their energy usage and preferences. The table shows that most respondents (92.8 per cent) have some form of backup electricity, with petrol generators being the predominant source (75.2 per cent of respondents). It was also interesting to observe that despite this high prevalence of generators within the sample, the status quo (or opt-out) option in the DCE, which was based on maintaining the use of generators for backup energy, was not preferred among respondents (see Table 5-3 below) as only 8 per cent of respondents selected this option. Similarly, about 16 percent of respondents had an inverter and battery system installed in their homes. The inverters and batteries are typically used to store power whenever the intermittent grid electricity supply is available. Households use the combination of inverters and batteries as an additional layer of insulation against power cuts.

Within the sample, 3.8 per cent of respondents owned multiple forms of backup energy (petrol, diesel generators, solar systems) and were connected to the grid, perhaps to fully insulate themselves against blackouts. Adoption of alternative clean sources of backup energy within the sample is relatively small as only 8.3 per cent of households report ownership of a solar home system[39], demonstrating the relatively low uptake of solar energy. However, of the 348 respondents (53.6 per cent of the sample) who had considered buying a solar system at some point in the past, 89 per cent do not currently have a solar system installed. This high rate of non-adoption might be due to the high initial costs of purchasing a solar system and the lack of access to financing schemes. Upfront prices for 5KW solar home systems can range from ₦825,600 -

[39] Solar, inverter and batteries.

₦1,021,000[40] (US$2,690-US$3,326), which is between two to three-and-a-half times an average individual's household income within the sample, ₦284,284[41](US$926).

Over half of the respondents spent less than ₦20,000 (US$65) a month on running their generators and less than ₦10,000 (US$32.5) on-grid electricity. From Monday to Sunday, the daily electricity supply from the grid is between 5 to 10 hours, which highlights the dire situation of publicly provided electricity. Perhaps, this explains why 65.5 per cent of respondents expressed dissatisfaction with electricity from the local utility, Ibadan Electricity Distribution Company (IBEDC). Most respondents (84 per cent) consider electricity availability as a very important factor when deciding to buy or build a new home. Most respondents (83 per cent) also expressed concern about the health impacts of using a backup generator to supply electricity.

[40] This comparison was based on 2019 estimates of a 5KW solar home system price (for a standard 2-bedroom apartment).

[41] This mean income is estimated based on a conversion of the income variable from a grouped numerical variable to interval data. Median income within the sample was within the range of ₦100,000 to less than ₦250,000.

Table 5-2: Respondent energy preferences (N = 649)

Variable	Description	Frequency	%	Population (Urban)
Backup energy ownership (%)	The household has a form of backup electricity	594	92.8	
Petrol Generator ownership (%)	The household has a petrol generator (in addition to other sources)	481	75.2	34.4% average (no disaggregation between petrol and diesel)
Diesel Generator ownership (%)	The household has a diesel generator (in addition to other sources)	101	15.8	
Inverter and battery ownership (%)	The household has inverters and batteries (in addition to other sources)	102	15.9	
Solar ownership (%)	The household has a solar system (in addition to other sources)	53	8.3	
Multiple sources of backup energy owned	The household has a petrol generator, solar, inverter and batteries	24	3.8	
Monthly expenditure on Generators	Less than ₦20,000 (highest occurrence)		52.1	
Average monthly expenditure on grid electricity	Between ₦5,000 to less than ₦10,000	206	33.1	
Hours of grid electricity supply (Weekdays)	Between 5-less than 10 hours	207	33.3	7 hours per day
Average hours of grid electricity supply (Weekends)	Between 5-less than 10 hours	237	37.8	
Electricity availability: is a very important consideration for me when I want to buy or build a new home	Agree (highest occurrence)	539	84	
Dissatisfaction with grid electricity supply	Agree and Somewhat Agree	421	65.5	
Concerned about the health impacts of using a backup generator	Agree and Somewhat Agree	539	83.1	

The responses of individuals to all the DCE questions are presented in Table 5-3. The table shows that most respondents (76%) tend to pick the cleaner alternatives presented to them (Option A and B) rather than remaining with the option with their current backup generator (8%) when accounting for missing values. Considering only the valid responses to the DCE, it can be seen that this figure is much higher, showing that most respondents (91%) picked either Option A or Option B compared to just 9% of respondents who chose to remain with the status quo option of home with a backup generator.

When considering the alternatives chosen, on average, more than half of the respondents (52%) that answered the DCE questions picked the second alternative (option B). Likewise, a comparison of valid responses between the two alternatives, excluding the status quo option, shows that 57% of respondents picked option B over option A. When decomposing this to individuals with generators only, it was seen that there is an even higher tendency to pick a cleaner alternative. This perhaps highlights the preference of current generator owners for alternative sources of backup energy for their homes.

Table 5-3: Respondent Distribution of choices among DCE alternatives

	Choice among alternatives			**Total**	
	Option A	**Option B**	**Status Quo**	**Clean Options**	**Status Quo**
Avg. Frequency	212	284	51	495	51
Avg. Per cent	33	44	8	76	8
Avg. Valid Per cent	39	52	9	91	9
DCE alternatives breakdown excluding status quo					
	Option A		**Option B**	**Total**	
Avg. Frequency	212		284	495	
Avg. Per cent	43%		57%	100	

5.3.2. Analysis of preference data

In addition to the DCE attributes, some individual-specific variables adjudged relevant to the models were included. Overall, it was noticed that the inclusion or exclusion of individual-specific variables did not significantly impact overall model fit and attribute parameters. The base model was estimated without individual-specific variables, while other models were included to capture them. The results from the preference data analysis are presented below. The outcome variable (RES) depicts the choice taken by respondents. It is used as the dependent variable because it allows us to capture the systematic components of the utility derived from the choice selected by the respondent.

5.3.2.1. *Mixed Logit Model Results*

In the base MXL model in Table 5-4, only the five DCE attributes were included to examine the effect of these attributes on the expected probability of choosing an alternative. The base model was estimated with all attributes being random and normally distributed based on the recommendation by Meijer and Rouwendal (2006) and Sagebiel (2017); however, there are other possibilities for this. According to Sillano and de Dios Ortúzar (2005), fixing the cost parameter produces biased estimates. Others have opined that the cost parameters can be non-random (Revelt and Train, 1998; Carlsson and Martinsson, 2008). Therefore, it was decided to either treat all attributes as random (base model) or randomize the cost parameters only in the subsequent model specifications (model 2). The random parameters were assumed to be correlated, and 1000 Hammersly draws were used for the simulation. The integration point was set at 1000 to ensure the stability of results.

The significant standard deviations of the parameters in the base model suggest unobserved heterogeneity in preferences. The Prob>Chi2 values of zero point to the statistical significance of the model. The sign and size of the coefficients depict the effect of each attribute and individual-specific variable on the expected probability of choosing an alternative.

Table 5-4: Mixed Logit Estimates of Household Choices - Base model

Attributes	Coefficient	(Std. Err.)
Backup (solar and inverter)	0.172*	0.089
No Pollution	0.765***	0.085
Energy trading (Buying and selling)	0.376***	0.068
House price	-0.136**	0.060
Backup price	-0.725***	0.091
Alternative Specific Constant (ASC)	2.026***	0.187
Standard deviations of the random parameters		
Solar SD	0.018*	0.238
Pollution SD	0.559***	0.372
Energy trading SD	2.378***	0.297
House price SD	0.159***	0.017
Backup price SD	1.412***	0.299
No of Obs.	6,549	
Log-likelihood	-1916.606	
Prob>chi^2	0.000	
* Significant at 10% **Significant at 5% *** Significant at 1%,		

The results show that all attributes are significant. The coefficient of the backup variable is positive and significant. It shows that the presence of a solar and inverter system is a positive and significant predictor of household choice for a new home. It is also interesting to find that the "no pollution" variable positively and significantly affects the expected probability of choosing a home. This suggests a difference in preferences when there is still a possibility of experiencing local noise and air pollution from generator use (albeit low levels) compared with when this is eliminated.

The coefficient of the energy trading variable shows that consumers are drawn to the possibility of trading energy with their neighbours in a community setting, as the variable has a positive and significant effect on the expected probability of household choice. Chapter 6 further distinguishes between preferences for both levels of energy trading (buying and selling). The two cost parameters are negative, in line with the theory of consumer choice, suggesting that individuals are less likely to select houses with higher prices. Similarly, the results show that respondents were less likely to pick the more expensive backup option presented to them in the DCE.

Individual-specific variables were progressively included subsequently in Model 2 to examine the effect of these variables on choice (see Table 5-5). These specific variables show how individual characteristics and attitudes towards energy affect the expected probability of picking between a cleaner alternative and the status quo option. However, most of these variables were not statistically significant, except the variable included capturing electricity experience, age and education of the household head. The more educated the household head is, the more likely they are to select a cleaner alternative than the status quo option. This might be because they are more aware of the benefits of adopting cleaner and quieter energy options and the health challenges associated with prolonged exposure to generator use. This finding is in line with studies in the literature (Sundt and Rehdanz, 2015d; Zhang *et al.*, 2016) that highlight the role of information and awareness of the clean and quiet benefits of adopting cleaner energy options like solar PV.

Table 5-5: Mixed Logit Estimates of Household Choices – Model 2

Attributes	**Coefficient**	**(Std. Err.)**
Backup (solar and inverter)	0.0837	0.1169
No Pollution	1.1194***	0.1138
Energy trading (Buying and selling)	0.5269***	0.1069
House price	-0.0300***	0.0096
Backup price	-1.3969***	0.1874
Case Variables		
Age	0.4881***	0.1628
Female	0.5184	0.4217
Household income	0.09	0.1263
Household head education	0.0335***	0.0279
Household size	0.1673	0.3444
Households with children	0.7401	0.4622
Electricity experience	-0.2378***	0.0727
ASC	1.2317	1.5405
No of Obs.	5,547	
Log-likelihood	-1432.477	
Prob>chi^2	0	
* Significant at 10% **Significant at 5% *** Significant at 1%		

5.3.2.2. *Latent Class Logit Model Results*

A latent class logit model is estimated to examine the role of individual characteristics on preferences and investigate the degree of heterogeneity among respondents in the DCE. In the LCL estimation, the coefficient sign represents whether a given class has positive or negative preferences for a particular attribute. AIC and BIC measures were applied to determine the optimal number of latent classes. Various classes (2, 3, 4 and 5 classes) were attempted; however, models with 4 and 5 classes did not converge. The latent class model with 3 classes was selected for analysis as it had lower AIC and BIC values (see Table 5-6 below).

Table 5-6: Number of latent classes

Model	Log-likelihood	df	AIC	BIC
3 classes	-1560.369	23	3166.738	3297.572
2 classes	-1639.398	15	3308.795	3394.122

The results of the LCL are given in the Class-Specific Model in Table 5-7 below. The coefficients are relative to those of class 3, which acts as a baseline. From this analysis, three groups (classes) of respondents with similar (latent) preferences within the sample emerge. Based on the results, class 1 tagged "moderate adopters" (41.7 per cent of respondents), class 2 can be termed as "likely avoiders" (8.7 per cent), while class 3 can be marked as "likely adopters" (49.6 per cent). This characterization aligns with the choice distribution presented in Table 5-3 above.

The three latent classes of the respondents were classified by the significance of the attributes. Preferences of individuals in class 1 (moderate adopters) show that they prefer cleaner backup options and are most likely to engage in energy trading (selling energy to neighbours). Respondents in class 1 preferred a home where the backup option was solar. In class 2 (likely avoiders), most parameters were insignificant (except house price), indicating that individuals in this class preferred the status quo and had a negative response to an increase in the house price. In class 3 ("likely adopters"), the significance of the backup variable suggests that individuals in this class prefer cleaner backup options (solar and inverter). Similarly, the significance of the "no pollution" variable in class 3 suggests that individuals in this class are intolerant to noise and air pollution and are likely not to prefer the status quo option. Furthermore, in class 3 e, the energy trading (selling) variable is insignificant, which indicates that respondents in this category are more likely concerned about the intrinsic benefits than participating in energy trading.

Table 5-7: Estimation Results, Latent Class Logit Model

Class Specific Model			
Variable	**Class 1**	**Class 2**	**Class 3**
Backup (solar and inverter)	0.325	-0.272	1.841**
No Pollution	0.329*	0.302	5.355***
Energy trading (selling)	1.104***	0.042	0.016
House price	0.071***	-0.140**	-0.238***
Backup price	0.040	-0.697	-4.188***
Class Share	41.7%	8.7%	49.6%
N	4,983		
Log-likelihood	-1136.140		
Prob>chi^2	0.00		

* Significant at 10% **Significant at 5% *** Significant at 1%

5.3.3. Comparing Results of the MXL and LCL

Preference heterogeneity is a desirable feature of discrete choice modelling since, in reality, preferences vary across individuals (Boxall and Adamowicz, 2002). While both the estimated MXL and LCL models account for preference heterogeneity, the latent class analysis results reveal heterogeneity in preferences and allow for the identification of varying preferences in 3 distinct latent classes, or “segments”, as outlined above. The identified differences in preference across classes captured by the LCL are often difficult to depict in the MXL (Sagebiel, 2017). However, both models appear to be similar with respect to choice probabilities. Table A-3 in Appendix 11 gives the results of a linear regression of the choice probabilities of the MXL on the LCL following the post-estimation recommendation of Sagebiel (2017). The regression indicates that the choice probabilities of the LCL and of the MXL are highly correlated. The variation of the choice probabilities of the LCL explains MXL choice probability variation by 94.9%, suggesting similar choice probabilities across both models. The intercept suggests that the choice probabilities of the MXL are -0.003 when the LCL choice probabilities are zero. The coefficient of 1.01 suggests that a unit increase in the LCL choice probability leads to an equivalent increase in the RPL choice probability. In essence, there is a one-to-one choice probability in both models.

5.3.4. Willingness to Pay Estimation

To estimate the WTP for attributes of a product using DCE data, the coefficient of the attribute for which the WTP is being calculated is simply divided by the coefficient of the monetary attribute. This means that the WTP estimation is done using implicit prices, which reflect the trade-off respondents are willing to make between various characteristics of attributes of households and payment. In other words, the WTP is estimated as the marginal rate of substitution between an attribute and the cost attribute. The WTP for the attributes are calculated based on the method proposed by Krinsky and Robb (1986), where the WTP is defined by the function below;

$$WTP = \frac{-\hat{\beta}attribute}{\hat{\beta}cost}$$

Table 5-8 and Table 5-9 give the WTP values for the MXL and LCL models, respectively. The estimates are converted to monetary figures by multiplying them by ₦1 million to reflect the backup and house prices depicted in the choice experiment. The RPL results show that an average respondent is willing to pay approximately ₦12.4m (US$40,497) for a house with no noise and air pollution. The LCL reveals differences in preferences, among classes, with the mean WTP of ₦2.7m largely driven by the values from class 3 (likely adopters). The LCL estimates for backup prices also reveal a mean WTP of ₦3.7m for backup options without pollution, with minimal values derived from the RPL model. Detailed WTP analysis for each class is available in Table 5-10.

Table 5-8: Willingness to Pay Values for House

House Price

Variable	**MXL**		**LCL**	
	Mean	**SD**	**Mean**	**SD**
Backup (Solar and Inverter)	0.9	0.6	-0.2	0.1
Pollution (none)	12.4	8.3	2.7	1.8
Energy trading (selling)	5.9	3.9	-3.3	2.2

Table 5-9: Willingness to Pay Values for Backup

Backup Price

Variable	**MXL**		**LCL**	
	Mean	**SD**	**Mean**	**SD**
Backup (Solar and Inverter)	0.03	0.02	0.2	0.6
Pollution (none)	0.3	0.2	3.7	3.2
Energy trading (selling)	0.6	0.1	-0.4	9.9

Table 5-10: Detailed Willingness to Pay Values from LCL Model

House Price

LCL	**Class1**	**Class2**	**Class3**	**Mean**	**SD**
Backup (Solar and Inverter)	-6.0	-0.5	5.1	-0.2	0.1
Pollution (none)	-6.5	6.5	23.9	2.7	1.8
Energy trading (selling)	-64.9	-11.3	46.2	-3.3	2.2
Energy trading (buying)	-49.2	-10.2	46.4	-1.4	1.0

Backup Price

LCL	**Class1**	**Class2**	**Class3**	**Mean**	**SD**
Backup (Solar and Inverter)	0.84	-0.62	0.42	0.07	0.05
Pollution (none)	0.91	8.16	1.96	1.22	0.82
Energy trading (selling)	9.11	-14.02	3.78	-0.13	0.09
Energy trading (buying)	6.91	-12.65	3.79	-0.22	0.15

5.4. Conclusion

This chapter focused on the *personal* benefits of a clean *local* environment that solar energy can also provide. This chapter used a DCE to provide insights into preferences for clean and quiet solar PV backup electricity on a residential estate and energy trading preferences. Applying a Mixed Logit and Latent Class analysis, this chapter found that consumers are interested in dwelling in homes with cleaner backup alternatives, including solar and inverters, compared with the status quo option of residing in homes with petrol or diesel generators. This study also found that consumers are interested in energy trading, with preferences for selling over buying excess electricity to neighbours. The next chapter further examines preferences for energy trading.

6. CHAPTER 6: VALUING PREFERENCES FOR ENERGY TRADING AMONG ESTATE RESIDENTS IN A NIGERIAN CITY.

Chapter Overview

This chapter presents quantitative findings from the survey on preferences for energy trading. Specifically, this chapter examines how independence aspirations and financial benefits influence the possibility of P2P energy trading. A version of this chapter has been submitted for publication in the Energy Policy Journal.

6.1. Introduction

As outlined in Section 2.2, the emerging literature on P2P energy trading has largely covered technical, socioeconomic, policy, and regulatory aspects of P2P energy trading. From the supply side, there is an understanding that profitability is key to making P2P energy trading viable (Park and Yong, 2017). However, there is limited evidence from the end-users perspective on the importance of financial benefits for engaging in energy trading, particularly in the global south, especially Africa. While there is evidence in the literature on the technical aspects of P2P energy trading, there is still limited evidence from the global south on the socioeconomic aspects, such as consumers' inclination to participate in such systems. For example, the structured literature review by Adams et al. (2021) found only one study on the social and economic value produced by P2P in Africa.

Whilst the literature review in Section 2.2 has shown that P2P energy trading can provide a range of benefits to individuals who participate, including making additional income, cost savings, investment opportunities, increased energy independence, and environmental benefits, there are several reasons why people might not be keen on participating in P2P energy trading for the financial and independence benefits they might derive from it. For example, people may be simply unaware of the financial benefits of electricity trading or may not understand how it works. Without sufficient knowledge or understanding, people may be hesitant to participate in electricity trading. Also, P2P trading can be a complex process involving a range of technical and legal considerations that can make it difficult to understand the potential financial benefits. Furthermore, as with any trading activity, P2P energy trading involves some level of financial risk, depending on the prevalent pricing regime and because demand can fluctuate over time. There may be some hesitation to participate in P2P electricity if the perceived risks are seen as too high, especially if the potential financial benefits are not sufficient to justify the risk.

Therefore, this chapter examines if people are less likely to trade electricity if it would provide a financial benefit by focusing on the financial benefits (increase in income and reduction in energy expenses) and the independence benefits of P2P by examining if it can prove attractive in contexts where people want independence from the local energy provider.

The concept of autarky in energy preferences has been discussed in the literature primarily in the context of western developed countries (Müller *et al.*, 2011; Korcaj, Hahnel and Spada, 2015; Engelken *et al.*, 2018; Kalkbrenner, 2019) with little evidence of studies examining this concept in developing countries in the global south. Evidence from countries such as Germany and Australia shows that people are increasingly adopting distributed solar PV to gain independence from the electricity grid (Engelken *et al.*, 2018; Liu *et al.*, 2019; Sabadini and Madlener, 2021). In Nigeria, due to broader governance failures, local communities have taken responsibility for other important community infrastructure such as speedbumps, water supply, and streetlights. Therefore, this chapter explores if the energy decision of households in contexts like Nigeria is such that individuals want independence and would take decisions to meet their energy needs rather than rely on an erratic grid supply. Indeed, evidence from the World Bank shows high levels of dissatisfaction with the electricity supply in Nigeria, as 74 per cent of surveyed electricity consumers expressed dissatisfaction with the electricity supply and 78 per cent received less than 12 hours of power supply daily (Odutola, 2021). In Nigeria, challenges with the grid also present an opportunity for alternative means of consistent electricity supply and distributed energy resources to play a key role in the electricity supply mix for households.

This chapter explores whether the autarky benefits from energy trading prove attractive to individuals who seek independence from the grid, perhaps because of challenges with inconsistent supply, inadequate metering, estimated billing, and tariff increases. Furthermore, this study distinguishes between preferences for buying and selling electricity on a P2P energy trading platform in a residential estate setting.

The remainder of this chapter is organised as follows: Section 6.3 outlines the data and analytical approach employed. Section 6.4 presents the results from empirical analysis and discusses the results. Finally, Section 6.5 concludes the chapter.

6.2. Chapter Objectives and Hypothesis

Given the potential role that RE and P2P energy trading can play in supporting sustainable and reliable energy provision, as outlined in Section 1.2.5.1, this chapter examines how *financial benefits and autarky aspirations* influence preferences for P2P energy trading in a residential estate setting. Specifically, this chapter investigates the following:

(i) Whether individuals are motivated to trade energy for the financial benefits they can obtain from trading energy within a residential estate setting; and

(ii) Whether P2P energy trading can prove attractive in contexts where people want independence from the local energy provider;

(iii) What are the characteristics of individuals that are interested in buying and selling energy on a P2P energy trading platform?

6.2.1. Hypothesis

The following hypotheses are tested to achieve the three objectives outlined above,:

H_0^1: People are less likely to trade electricity if it would provide a financial benefit (increase in income and reduction in energy expenses)

H_0^2: *Hypothesis 1B*: People are less likely to trade electricity if it would provide independence from the local electric utility (addressing autarky expectations)

H_0^3: Participants do not differ in their sensitivity to variations in both factors (financial benefit and independence), resulting in different prosumer groups with energy trading preferences and choice of dwelling.

H_0^1 addresses the role of financial benefits on the decision to engage in P2P energy trading: Rejection of this hypothesis thus suggests that individuals might be motivated to trade energy for the financial benefits they can gain from trading energy within a community setting.

H_0^2 addresses independence/autarky expectations: The main thrust of this hypothesis is to test if P2P energy trading can prove attractive in the context where people want independence from the local energy provider. Given challenges with inconsistent supply, inadequate metering estimated billing, and tariff increases, amongst others. As we have seen in other situations, such as local community security decisions or constructing local infrastructure such as speedbumps, local communities have demonstrated taking decisions into their own hands, given the neglect of the public system to address these issues. Rejection of this hypothesis suggests that people would be interested in P2P energy trading if it would provide independence from the local electric utility, thereby allowing individuals to become more energy-independent.

H_0^3 addresses differences in preferences among respondents: The rejection of this hypothesis implies that it is possible to distinguish between various categories of respondent preferences for P2P energy trading and that respondent preferences for P2P energy trading are not homogenous.

6.3. Data and Methods

6.3.1. Data

Data used in this chapter is based on the survey outlined in Section 3.5. The survey was designed to collect information on consumer preferences for electricity and included a section on P2P energy trading which is the focus of this chapter.

To investigate if people are more likely to trade electricity due to *financial benefits,* this thesis focuses on benefits in the form of *additional income* and *reduction in energy expenses* occasioned by engaging in P2P energy trading. Similarly, *autarky benefits* are investigated using responses to two survey questions. The first question examined interest in P2P energy trading to *reduce reliance* on grid supply.

The second question examined interest in buying electricity from the P2P energy trading service to get a *constant power supply*. This chapter examines responses to a choice experiment that presented hypothetical home choices with the possibility of energy trading. Respondents were presented with the hypothetical choice of selecting homes with four attributes that define the possible characteristics of the new home in a new estate, with one of the attributes presenting the possibility of energy trading (see Table 3-2).

The analysis estimates the effect of variables depicting financial benefits from trading energy and autarky preferences on home choice[42]. Interactions of participants' home choice decisions and the buying and selling levels of the energy trading attribute of the choice experiment serve as a proxy for interest in energy trading. They are included as dependent variables for the individual regressions. The dependent variables allow for examining preferences for buying and selling energy via a hypothetical P2P energy trading platform.

---

[42] Where homes can include the possibility of engaging in energy trading by selling or buying energy

6.3.2. Methods

Two logistic regression models were estimated where the two financial and autarky variables serve as key independent variables. Table 6-1 outlines the autarky and financial benefit variables alongside the socio-demographic variables included in the model. The regression models also include socio-demographic variables like age and household income. Different model specifications and estimation methods were used, with no significant changes to the results, thus reinforcing the findings.

The logistic regression modelling approach used in this study is based on similar studies (Fell, Schneiders and Shipworth, 2019; Bao *et al.*, 2020; Hackbarth and Löbbe, 2020; Watson *et al.*, 2020) that use a similar regression approach to examine interest in P2P energy trading and solar PV based on household survey data.

Collinearity checks were conducted, and collinearity was not detected. Specifically, the *collin* command in Stata was used to check the variance inflation factor (VIF) for the variables used in the estimation. None of the VIF values was above 2 (the reliability of supply variable was 1.78 and 1.76 in the buying and selling models, respectively), indicating that collinearity was not a problem with this and any other variables in the model.

Table 6-1: Description of variables used for energy trading analysis

Variable Name	Definition	Category	Yes (%)	No (%)	Unsure (%)
Additional money	I would be interested in selling electricity through the P2P energy trading service to make some additional money	Financial benefit	82	10	8
Lower expenses	I would be interested in buying electricity from the P2P energy trading service to get electricity at a cost lower than current expenses on power	Financial benefit	92	5	3
Reduce reliance on grid electricity supply	I would be interested in buying electricity from the P2P energy trading service to reduce dependence on electricity supply from the local electric utility	Autarky	88	6	6
Constant power supply	I would be interested in buying electricity from the P2P energy trading service to get a constant power supply	Autarky	93	3	4
Socio-demographic variables					
Age	Respondent's age in categorical levels				
Household income	Average monthly household income in categorical levels				
Household education	Respondent's highest education in categorical levels				
Household size	Respondent's household size in categorical levels				
Children	Households living with children				
Sex	1 if the respondent is female and 0 if the respondent is male				

6.4. Results and Discussion

Overall results from the logistic regression analysis revealed that financial benefits and autarky aspirations are vital factors influencing participation in energy trading. Results from the logistic regression models[43] are presented in Table 6-2 and Table 6-3 below.

Table 6-2: Estimation Results from Buying Model

	Choose a home with Buying Option			
VARIABLES	Coefficient	Std Err	Odds ratio	%
Additional money	0.219**	(0.087)	1.2473	24.5
Lower expenses	0.360*	(0.192)	1.3171	43.3
Reduce reliance	1.187***	(0.227)	2.5447	227.7
Constant supply	0.267	(0.247)	1.1914	30.5
Individual specific variables				
Household size: 3+ people	0.813***	(0.283)	1.3806	125.4
Children	0.748**	(0.351)	1.4304	111.2
Female	0.573***	(0.124)	1.3228	77.3
Age: 18-29 (reference category)				
Age: 30-39	0.473**	(0.191)	1.2373	60.5
Age: 40-49	1.075***	(0.200)	1.5288	193
Age: 50-59	0.870***	(0.212)	1.3392	138.6
Age: 60 and above	0.771***	(0.239)	1.2899	116.2
Household income: Less than ₦100,000 (reference category)				
Household income: ₦100,000 – < ₦250,000	0.409*	(0.216)	1.2149	50.5
Household income: ₦250,000 – < ₦500,000	0.792***	(0.220)	1.4197	120.9
Household income: ₦500,000 – < ₦750,000	1.107***	(0.260)	1.3818	202.7
Household income: ₦750,000 and above	1.178***	(0.257)	1.433	224.8
University Education	0.356**	(0.160)	1.1655	42.8
Estimation Statistics				
Observations	2,997			
LR chi2(16)	228.32			
Prob > chi2	0.000			
Log-likelihood	-939.58			
Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.10				

[43] The interpretation of the results each variable included in the model is done while holding all other variables at a fixed value.

Table 6-3: Estimation Results from Selling Model

	Choose a home with a Selling Option			
VARIABLES	Coefficient	Std Err	Odds ratio	%
Additional money	0.218***	(0.060)	1.2437	24.4
Lower expenses	0.221**	(0.103)	1.2467	24.7
Reduce reliance	0.154*	(0.084)	1.1665	16.6
Constant supply	0.165	(0.127)	1.1792	17.9
Individual specific variables				
Household size: 3+ people	0.553***	(0.174)	1.738	73.8
Children	0.479**	(0.230)	1.6139	61.4
Female	-0.056	(0.092)	0.9455	-5.5
Age: 18-29 (reference category)				
Age: 30-39	0.056	(0.120)	1.0575	5.7
Age: 40-49	0.002	(0.137)	1.0017	0.2
Age: 50-59	0.019	(0.153)	1.019	1.9
Age: 60 and above	-0.150	(0.160)	0.861	-13.9
Household income: Less than ₦100,000 (reference category)				
Household income: ₦100,000 – < ₦250,000	-0.076	(0.124)	0.9271	-7.3
Household income: ₦250,000 – < ₦500,000	-0.050	(0.132)	0.9516	-4.8
Household income: ₦500,000 – < ₦750,000	-0.026	(0.177)	0.974	-2.6
Household income: ₦750,000 and above	-0.517***	(0.190)	0.5965	-40.3
University Education	0.259**	(0.108)	1.2961	29.6
Estimation Statistics				
Observations	3175			
LR chi2(16)	106.43			
Prob > chi2	0			
Log-likelihood	-1610.174			

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.10

6.4.1. What motivates respondents to engage with P2P energy trading?

6.4.1.1. ***Financial benefits***

Starting with the financial benefits variables, most respondents show interest in energy trading to make additional money (82 per cent) and reduce expenses on power (92 per cent) (See Table 6-1). The empirical analysis shows that residents interested in selling electricity through P2P to make more money are more likely to select a home to buy and sell surplus energy, as the coefficient of the *additional money* variable is significant in the two estimated models. For these residents, the odds of selecting a home with the option of buying and selling surplus electricity are higher than the odds of not selecting such a home. In percentage terms, the odds of interest in P2P energy trading to make additional money are about 24 per cent higher than the odds of not being interested in buying and selling regressions. The estimation of interest in selling electricity suggests that individuals value the prospective benefits of making additional money from P2P energy trading.

From the viewpoint of purchasing energy, the results of the "*lower expenses*" variable in the buying regression suggest that respondents are drawn to engaging in P2P energy trading if it allows them to source energy to reduce overall expenses on power. Similarly, the results of the effect of the *lower expenses* variable in the selling regression suggest that respondents are interested in participating in P2P energy trading if it allows them to reduce overall expenditure on power. In percentage terms, the results show that the odds of respondents being interested in P2P energy trading to minimise overall power expenses are 43 per cent higher than the odds of having no interest in P2P energy trading in the buying regression and 25 per cent higher in the selling regression, respectively. In other words, respondents prefer energy trading platforms that offer them cost savings in the form of reduced expenses on power. This finding is similar to other studies that have also found personal economic benefits in the form of cost savings to be an essential driver in the decision-making processes regarding becoming a prosumer and P2P electricity trading (Palm, 2018; Mengelkamp *et al.*, 2019; Hackbarth and Löbbe, 2020; Karami and Madlener, 2022).

6.4.1.2. *Autarky preferences*

Table 6-1. shows that most respondents are interested in the independence benefit of P2P energy trading in the form of reduced reliance on grid electricity supply (88 per cent). The regression results in Table 6-2 further reveal that residential consumers who want to reduce dependence on grid electricity supply were particularly likely to choose a home with the option to *buy* P2P electricity. Holding all other variables at a fixed value, respondents keen to *"reduce reliance"* are 228 per cent more likely to choose a home with the option to buy P2P electricity, while the odds are 17 per cent higher in the case of selling. The significance of the variable that captures reduced reliance from the local utility from both a selling and buying energy perspective reinforces the linkages between independence aspirations and reduced reliance on the electricity grid within the sample. This finding differs from Ecker, Spada and Hahnel (2018), who found that focusing on autarky benefits makes people less inclined to trade because of the higher relative value of self-generated energy.

However, interest in having a "*constant power supply*" does not significantly affect choosing a home with energy trading capabilities, despite the descriptive results showing high-interest levels in energy trading to get a constant power supply (93 per cent). Whilst individuals within the sample might be used to unreliable power supply; the results suggest study participants were keen on P2P energy trading primarily from the perspective of gaining independence from the local utility and, to a lesser extent, improved reliability. The limited preferences for energy trading from a reliability perspective also suggest that the interest in P2P energy trading might be less about reliability and similar to other contexts like Germany and Australia with growing interest in self-generation through distributed solar PV to gain independence from the electricity grid (Engelken *et al.*, 2018; Liu *et al.*, 2019; Sabadini and Madlener, 2021).

6.4.2. Individual characteristics and interest in P2P energy trading

Regarding the influence of socio-demographic preferences, the results also show that larger households of three or more people are more interested in P2P energy trading from both the perspective of buying and selling energy. The odds of these respondents with medium-large households being interested in P2P energy trading to buy energy are 125 per cent higher than in smaller households (with two or fewer individuals). Similarly, the odds for interest in selling power are 74 per cent higher than in smaller households. As households with three or more people tend to be families, this finding suggests that families might be interested in both buying and selling aspects of P2P energy trading. This finding is also similar to evidence in the literature that larger households of more than three people tend to be more interested in participating in P2P energy trading (Mengelkamp *et al.*, 2019; Hahnel *et al.*, 2020).

Similarly, this study finds that households living with children are more likely to be interested in the buying and selling aspects of energy trading than respondents not living with children. The odds of households living with children are 111 per cent higher in the buying regression and 61 per cent in the selling regression, respectively. This finding further indicates the attractiveness of energy trading to families who might be keen on trading energy to meet the diverse needs for power within the household.

This study finds sex-based differences in P2P energy buying preferences: female respondents are more likely to select a home with the option of buying energy when compared to male respondents. The analysis shows that the odds of female respondents selecting a home with the possibility of purchasing energy are 66 per cent higher than for male respondents. Women's interest in buying power from the P2P energy trading platform might be because they are particularly impacted by unreliable residential electricity supply, which can make their household activities more burdensome. Therefore, women in such contexts familiar with the challenges of erratic electricity supply can be targeted for P2P energy trading by showcasing the possibility of buying energy from others.

The results show that age has mixed effects on interest in P2P energy trading. The findings from the buying regression show significant interest in buying electricity among all other age categories with respect to the reference category (the youngest age group, 18 to 29). Conversely, there appears to be no significant effect of age on interest in selling energy to neighbours as none of the age categories are statistically significant (compared with the reference category). These findings indicate a broader appeal of buying energy P2P among different age categories within the study sample. In contrast, Hackbarth and Löbbe (2020) found that the respondents most open to P2P energy trading in a German sample are within the age range of 40-69.

The results for household income indicate that it influences interest in buying electricity through P2P energy trading. Specifically, the results show that the odds of selecting a home with the option of purchasing energy are higher for all income categories compared with the reference category (which is the lowest income bracket comprising respondents with household income less than ₦100,000). In percentage terms, compared with the lowest income bracket, the odds of selecting a home with buying option are, on average, 150 per cent higher for all other income categories. However, the results from the selling analysis reveal that the wealthiest household income categories (₦750,000 and above) are significantly less likely to be interested in selling electricity on a P2P energy trading platform than households in the lowest income bracket. When the selling analysis is estimated with the most affluent household income category (₦750,000 and above) set as the reference category, coefficients for all other income categories (particularly, the lowest income category earning less than ₦100,000) are positive and statistically significant. This suggests a broad appeal for selling electricity P2P among various household income categories, especially the least affluent households. The indicator for the most affluent household income categories suggests that the odds of these households being interested in selling energy on the P2P energy trading platform are 40 per cent lower than the lowest income bracket. This study's findings that wealthier households are more likely to be interested in buying energy from a P2P energy trading platform but less likely to be interested in selling power via P2P energy trading provide some nuance to the literature. For example, studies like Wilkinson *et al.* (2020) broadly find that those interested in P2P energy trading are wealthier but do not distinguish between buying and selling aspects of P2P energy trading.

Furthermore, more university-educated individuals are interested in P2P energy trading, and this finding holds for both buying and selling energy to neighbours. Specifically, the results show that the odds of selecting a home with the possibility of P2P energy trading are higher for university-educated individuals than for non-university-educated respondents within the sample. In percentage terms, the odds are 43 per cent higher in the buying analysis and 30 per cent higher in the selling analysis. This result is also similar to other findings in the literature that more educated individuals are more willing to participate in P2P energy trading (Hackbarth and Löbbe, 2020; Hahnel *et al.*, 2020). This finding that university graduates are more likely to be interested in P2P energy trading suggests that they can be targeted by companies seeking to develop P2P energy trading platforms in similar contexts.

6.5. Conclusion

In recent years, P2P energy trading has emerged as a model enabling decentralised trading of energy among energy prosumers. However, businesses, government policymakers and academia need evidence of its potential economic and social value. This chapter contributes to an emerging evidence base by examining the potential financial benefits and energy independence afforded by P2P energy trading; studies on this topic are important because they are limited. Moreover, the few studies conducted thus far have mostly been conducted in western developed countries. Therefore, this chapter's contribution is even more valuable; it presents evidence from a survey and choice experiment conducted in Ibadan, a city in Africa's most populous country, Nigeria.

Applying logistic regression analysis, this chapter finds that survey respondents are motivated to trade energy for the financial and autarky benefits they can gain from P2P energy trading within a residential estate setting. The financial benefits that interest respondents include earning additional income from P2P energy trading and reducing overall power expenses. The autarky benefit that drives interest in P2P is "reduced reliance" on the grid for electricity. Indeed, respondents who wanted to reduce their reliance on grid electricity were several times more likely to choose a home with a P2P buying option. Surprisingly in a city renowned for an unreliable electricity supply, the attraction of a constant power supply was not influential in either the buying or selling regression.

7. CHAPTER 7: SUMMARY AND CONCLUSION

Chapter Overview

This chapter summarizes the main findings from the study. It also highlights the limitations of the research and presents an agenda for future research. Section 7.1 outlines the key insights on the thesis research questions. Section 7.2 discusses the broader implications of the research on academia, policymakers, estate developers and industry. Section 7.3 discusses the challenges and limitations of the study, while section 7.4 discusses the next steps and avenues for further research.

7.1. Review of Research Questions

The main aim of this thesis was to provide empirical evidence on the preferences of residential consumers for solar PV and P2P energy trading as a form of backup electricity. To achieve this, three research questions were answered, as summarized below.

RQ1: What are the user preferences for solar PV as a form of backup electricity in a Nigerian residential setting?

To answer the first research question, this study used a DCE to provide insights into preferences for clean and quiet solar PV backup electricity on a residential estate and energy trading preferences. However, to design the DCE, this study employed a qualitative approach to identify relevant attributes for inclusion. Expert interviews revealing that some residents value living in clean and quiet areas led to the inclusion of a pollution attribute in the discrete choice experiment. In the quantitative phase, data from the DCE was analysed using the Mixed Logit and Latent Class models, as shown in Chapter 5. The analysis revealed that consumers are interested in dwelling in homes with cleaner backup alternatives, including solar and inverters, compared with the status quo option of dwelling in homes with petrol or diesel generators.

RQ2: What are the potential benefits that influence preferences for P2P energy trading among residential consumers?

This research question was also answered using data from the DCE and responses to a survey on preferences for engaging in P2P energy trading. Based on a logistic regression analysis, this study finds that survey respondents are motivated to trade energy for the financial and autarky benefits they can gain from P2P energy trading within a residential estate setting. The financial benefits that interest respondents include earning additional income from P2P energy trading and reducing overall power expenses. The autarky benefit that drives interest in P2P is "reduced reliance" on the grid for electricity. Indeed, this study found that respondents who wanted to reduce their reliance on grid electricity were several times more likely to choose a home with a P2P buying option.

RQ3: To what extent can the characteristics of the decision-maker explain these preferences?

This analysis presented in Chapters 5 and 6 helped answer this question. In chapter 5, the latent class logit model estimation revealed three groups based on their preferences for cleaner backup options and individual characteristics. The “likely avoider" group comprises individuals who are not interested in homes with solar PV for backup, are not interested in selling power and are very responsive to prices. The “moderate adopters” prefer cleaner backup options and are likely to engage in energy trading by selling excess energy to neighbours. Respondents in this category tend to be younger people who like a home with solar PV for backup power. The third group of respondents are “likely adopters” who prefer cleaner backup electricity options, are intolerant to noise and air pollution, but are not keen on energy trading. This group of respondents tend to be older people. Similarly, the role of individual characteristics on the preferences for P2P energy trading was explored further in Chapter 6, with a distinction between interest in buying and selling electricity P2P. The results revealed that those interested in purchasing were more likely to have families, be women, and be more affluent. Households interested in selling are more likely to be those with three or more people and kids.

7.2. Wider implications of results

This thesis has investigated the preferences and choices of individuals and households for solar PV as a form of backup electricity and preferences for engaging in P2P energy trading. As outlined below, the findings have important implications for academia, policymakers, estate developers and industry. However, this discussion is presented with a caveat that the results are based on a sample which might not apply to other contexts.

7.2.1. Academia

This thesis contributes to the academic literature by analysing consumer preferences for solar PV as a home attribute focusing on local benefits to residents. Furthermore, this thesis also contributes to the literature on preferences for solar by providing a fresh perspective on solar PV as a form of backup electricity rather than focusing exclusively on it to facilitate the clean energy transition. The study examines the benefits of the adoption of solar energy among residential energy consumers in Nigeria from their local perspective, not just from a global perspective. With the interest of some respondents in selecting cleaner options over the status quo, the study shows that there are individuals interested in dwelling in homes with cleaner and quieter backup energy options. This finding reveals the opportunity to frame the adoption of cleaner backup electricity options within this context from the perspective of the benefits collective adoption provides to the local environment. This benefit is in addition to reliability and other benefits such as aiding the clean energy transition and environmental benefits. The use of choice experiments to study preferences for backup energy and solar energy in Nigeria is also a novel contribution to the academic literature.

This study's findings that wealthier households are more likely to be interested in buying energy from a P2P energy trading platform but less likely to be interested in selling power via P2P energy trading provide some nuance to the literature. For example, studies like Wilkinson *et al.* (2020) broadly find that those interested in P2P energy trading are wealthier but do not distinguish between buying and selling aspects of P2P energy trading. The evidence in this thesis of a strong interest in P2P energy trading to reduce reliance on grid electricity supply indicates the attractiveness of P2P energy trading as an alternative for such consumers. This finding complements evidence in the literature on the interest of residential consumers in reducing dependence on utility supply (Bronski *et al.*, 2014; Agnew and Dargusch, 2017; Fares and Webber, 2017; Hanser *et al.*, 2017; Syed, Morrison and Darbyshire, 2020).

7.2.2. Policymakers

Insights from this thesis can aid policymakers in devising strategies to inform residential energy consumers about the benefits they can derive by using solar energy as their source of backup energy. The finding that respondents prefer solar over noise and air-polluting generators, whilst not surprising, has implications for the communication of solar energy benefits to households. These findings suggest that the clean and quiet benefits of adopting solar energy can be better communicated to households regarding how to reduce noise and air pollution within their surroundings, alongside other benefits such as reliability of supply. This is particularly important for stakeholders such as clean energy providers and policymakers interested in the increased uptake of solar energy among residential consumers.

This research provides further evidence of the role of residential solar energy in meeting the Nigerian government's policy goal to have RE contribute 30 per cent to on-grid generation capacity by 2030 (FGN, 2016). The findings demonstrate that whilst the electricity supply remains unreliable, there is an opportunity for solar PV to claim a much larger share of the backup electricity market. Policymakers and clean energy providers keen to increase the uptake of residential solar energy should highlight the clean and quiet benefits of solar energy for the residents themselves. It is also important to note the need for frameworks to improve access to credit to facilitate the widespread adoption of residential solar PV. Improved access to credit will help address challenges with the high upfront cost of adopting solar PV and make it easier for residential consumers to purchase SHSs beyond pico-PV or small SHS.

Findings also show that P2P energy trading can unlock additional benefits from standalone solar PV in the form of financial and independence benefits and supply flexibility. These benefits can foster increased interest in P2P energy trading of solar PV adoption. Consequently, Nigerian energy policymakers should put in place structures that support P2P for standalone solar PV. This enabling policy support can include allowing decentralised energy trading among residential consumers with solar PV. Given the increasingly important role of digital technology in the power sector, it is also essential for Nigerian energy policymakers to embrace P2P alongside other digital technological tools to meet energy needs. Nigeria has been identified as one of the countries best placed to embrace technological innovation and digitization in its renewable energy sector (Puig *et al.*, 2021). The country's policymakers can further harness this potential by developing and implementing a digitization roadmap for the energy sector. Such an energy sector digitization roadmap can incorporate P2P energy trading alongside other technological innovations for residential consumers to meet their energy needs. The road map can also outline appropriate policy incentives for the private sector and technology developers to create digital P2P energy trading platforms for residential energy consumers in the country.

In Nigeria, the adoption of P2P energy trading could bring several benefits, as identified in the thesis, for the consumers, including financial benefits and independence from the grid. However, beyond the individual consumers, P2P energy trading adoption has potential benefits, including facilitating increased access to electricity, greater efficiency in the energy market, and reduced reliance on diesel and petrol generators when coupled with clean energy sources like solar. To facilitate the adoption of P2P energy trading in Nigeria, some policy recommendations include the following:

Encourage the development of supporting infrastructure and technology for P2P energy trading: For P2P energy trading to be successful, it is necessary to have the necessary infrastructure and technology in place. This could include the development of smart grids, distributed energy resources (such as solar panels), and energy storage systems. Similarly, there is a need for increased policy support for the development of digital infrastructure, as P2P energy trading relies on the use of digital platforms to facilitate the exchange of energy. Therefore, it will also be important to support the development of digital infrastructure, such as high-speed broadband internet connectivity and secure payment systems, to ensure that P2P energy trading can be carried out smoothly.

Development a robust legal and regulatory framework to guide the advancement of P2P energy trading in Nigeria: It will be important to establish clear regulations and standards that govern the buying and selling of electricity among residential consumers, to ensure the increased adoption and operation of P2P energy trading. This should include rules around the ownership and operation of renewable energy systems and guidelines for selling and purchasing excess energy. The regulatory frameworks should also consider pricing, consumer protections, safety, data, and privacy issues.

Promote education and awareness of P2P energy trading in Nigeria: As the technology is still at a nascent stage of development, many people in Nigeria may be unaware of the potential benefits of P2P energy trading, so it will be important to promote education and awareness about this concept. It will be important to educate and raise awareness among individuals and businesses about the benefits of the P2P energy model and how to participate. This could include outreach efforts through media campaigns, workshops, and training programs. Furthermore, outreach efforts can include reaching out to local communities to communicate the benefits of P2P energy trading, such as those identified in this thesis, like financial and independence benefits.

Provide financial incentives for the adoption of renewable energy in Nigeria: P2P energy trading relies on the availability of excess energy that can be sold to others, thus, encouraging the development of renewable energy sources, such as solar and wind power, that can provide a reliable source of excess energy is pertinent. Therefore, policymakers can consider offering financial incentives, such as grants or subsidies, to encourage individuals and businesses to invest in renewable energy systems and participate in P2P energy trading. Such incentives can prove beneficial to increase the profitability of such systems in the near term, as the literature review in section 2.1.2 shows (see Nduka, 2022).

Encourage innovation, experimentation and collaboration between the digital technology and the energy sector: As P2P energy trading is a relatively new concept, there will likely be many different approaches to implementing it. Policy support to encourage innovation and experimentation will help to identify the most effective and efficient ways to facilitate P2P energy trading in Nigeria. Specifically, this would involve encouraging private sector involvement in the sector, especially start-ups. There are various ways policymakers can support innovation in this area. Policymakers can apply lessons from the development of other technology start-ups that are emerging in a key innovation hub in Nigeria. As seen in the broader technology sector in Nigeria, such start-ups can play a key role in developing and expanding P2P energy trading in Nigeria.

Policymakers can support the adoption of P2P energy trading by providing incentives and support for these start-ups to thrive, innovate and experiment in the sector. For example, the Nigerian Electricity Regulatory Commission (NERC) can set up regulatory sandboxes like the UK energy regulators[44], who have established a regulatory sandbox to support the development and testing of new technologies and business models in the energy sector (Ofgem, 2018). The regulatory sandbox can be designed to help start-ups navigate the typically complex regulatory environment surrounding the use of technology in a nascent part of the energy sector, like P2P energy. This can allow such start-ups to allow them to develop and test new ideas in the area of P2P energy trading technologies without incurring the full costs and risks associated with full compliance with prevailing regulations (Schneiders, 2021). Finally, policymakers can facilitate effective collaborations, partnerships and dialogue between different stakeholders, such as utilities, regulators, industry associations, start-up technology companies, and private sector players in the energy sector within and outside Nigeria who are keen on developing new technologies. Encouraging these partnerships and fostering a culture of collaboration can be useful to the successful adoption of P2P energy trading in Nigeria.

[44] The Office of Gas and Electricity Markets (Ofgem) and the Department for Business, Energy and Industrial Strategy (BEIS)

7.2.3. Estate agents and developers

This thesis's findings demonstrate an opportunity to develop and market clean, quiet estates that appeal to people concerned about the health impacts of generator use. Estate developers can promote the health and environmental benefits of dwelling in homes in estates where generator use is restricted and backup energy is generated from solar to individuals concerned about the health impact of generator use over time.

Real estate developers could capitalise on consumers' high levels of interest in the benefits of homes with P2P energy trading capabilities. They could incorporate homes with the capability of P2P energy trading when developing new housing estates where the use of diesel and petrol generators is restricted. Developers could target home-buyers that this study found are particularly interested in buying electricity via P2P energy trading: women, families, university graduates, and more affluent residents. A marketing strategy could be highlighting the value these prospective prosumers would *lose* if they missed out on P2P energy trading (Neumann and Mehlkop, 2020). Since reduced reliance on the grid was the most important determinant of interest in buying P2P electricity in this study, developers should emphasise that choosing a non-P2P development would maintain the consumer’s reliance on the grid.

Real estate agents can also support P2P energy trading by promoting the use of renewable energy technologies and the benefits of P2P energy trading to their clients. This can include providing information about the potential cost savings and environmental benefits of P2P energy trading and helping clients navigate the process of setting up and participating in P2P energy trading programs. Real estate agents can also support P2P energy trading by promoting properties that are equipped with renewable energy technologies and that would be suited to participate in P2P energy trading programs. This can make these properties more attractive to buyers or renters who are interested in sustainability and reducing their energy costs.

In addition, real estate agents can work with their clients to identify opportunities for installing renewable energy technologies on properties and connecting to P2P energy trading programs once these are further developed in Nigeria. This can include helping clients find financing options and providing information about local incentives and subsidies that may be available to support the deployment of renewable energy technologies. Finally, real estate agents can also support the adoption of P2P energy trading by working with policymakers to support the development of P2P energy trading. Specifically, real estate agents, under the auspices of the Nigerian Institution of Estate Surveyors and Valuers (NIESV), can advocate for policies that support the development of P2P energy trading, such as regulatory frameworks, incentives for developing estates with community renewable energy, that would allow the supply of solar PV that can be traded among residents, and infrastructure development like distribution grid infrastructure.

7.2.4. Industry

The research in this thesis has shown that residential electricity consumers are generally interested in the use of cleaner and quieter alternatives to diesel and petrol generators and are keen on the prospect of engaging in energy trading. This thesis also finds that, as respondents have a better experience with electricity supply from the grid, they are less likely to pick a cleaner alternative. This finding suggests that respondents are primarily interested in a steady electricity supply before considering the sustainable nature of such a power supply.

At a broader level, there is developmental assistance for the Nigerian electricity sector from international organisations such as the World Bank, providing financing through a Program for Result mechanism to the Nigerian electricity distribution companies, whereby they get paid based on service improvements. Participants in this research expressed dissatisfaction with electricity from IBEDC, the local electric utility, but individuals with a better electricity experience are less likely to select cleaner options. This finding suggests that if the reliability of grid electricity supply improves over the next decades, the appeal of solar for backup electricity might decline. However, solar PV has an opportunity to claim a large share of the backup electricity market in the meantime. As manufacturing costs of solar continue to fall and reduce the price of solar PV globally, this could further increase the appeal of solar PV in the near to medium term.

This study's findings regarding preferences for energy trading also have implications for potential private sector players in the energy trading industry, which is still nascent and emerging around the world. Industry players interested in developing real-world applications of P2P energy trading could target consumers within such contexts drawing on some of the insights showcased in this study. The results demonstrate the influence of individual characteristics on the preferences for P2P energy trading. With a growing interest in P2P energy trading, private sector companies are increasingly looking to develop real-world cases of P2P energy trading. This study shows how individual characteristics like age and household income affect preferences to participate in P2P energy trading markets within a residential setting in a developing country with an unreliable electricity supply. Specifically, the finding that older and more affluent people are more interested in buying energy from the P2P energy trading platform suggests that the benefits of purchasing power from neighbours should be showcased to them.

Conversely, the findings that younger and less affluent households prefer to sell excess power to neighbours within this sample suggest that they could be targeted by showcasing the benefits of selling excess energy to neighbours on a P2P platform. The findings demonstrate the need for a nuanced approach within contexts where individuals might be motivated to participate in community-based energy trading for financial gain and other considerations, such as independence from the electricity grid. Private sector players need to take this into account when considering ways to motivate estate residents to participate in energy trading systems, including through business models, ICT platforms, etc.

7.3. Reflections and Limitations of the study

Over the course of the PhD, I endeavoured to follow a detailed process to design and implement the study based on guidance from the literature, for example (Johnson *et al.*, 2013; Terris-Prestholt, Quaife and Vickerman, 2016; Johnston *et al.*, 2017). As this study used a mixed-method approach, efforts were made to ensure the robustness of each phase of the study. For example, the qualitative phase involved a detailed process ranging from conceptualisation of the research problem, identifying the appropriate experts to interview, in this case, real estate agents, designing the interview questions guide, seeking interviews with the real estate agents, taking notes and transcribing the interviews, coding the interviews in Nvivo, analysing the interviews to develop themes, and writing up the results.

Similarly, the quantitative phase involved designing the survey, with a specific emphasis on designing the DCE. Designing the DCE involved learning how to code in software I had not used before (R Software). The quantitative phase also involved identifying study participants, reaching out to the estates, seeking consent to participate in the residential estate meetings, hiring and training survey enumerators, conducting a pilot survey, carrying out the surveys, and coding the data into spreadsheets for analysis (in SPSS). After the data collection phase, converting the raw survey data from SPPS to R to align with the DCE experimental design and then conducting the statistical analysis in Stata. The quantitative analysis involved running various econometric models to generate the insightful results presented in Chapters 5 and 6 of the thesis. In both phases, I also sought and received separate ethical approvals to conduct the interviews, which involved extensive documentation preparation, such as the informed consent forms, participant information sheets, etc., available in the appendix.

Notwithstanding the efforts to follow a thorough process, some things did not go according to plan; therefore, the findings in this study have some limitations, which are acknowledged below.

The qualitative interviews could have accommodated more diverse views and benefited from a larger sample. This could have included identifying and reaching out to more female real estate agents through snowballing. Furthermore, the qualitative interviews could have captured views from a sub-sample of actual respondents in addition to the real estate agents. This would have given a well-rounded perspective on the nature of backup energy usage in households and further enriched that chapter.

A larger sample of respondents could have also enriched the diversity of opinions and views. The interviews should have had an expanded coverage in terms of the interview respondents to include the homeowners themselves. The interviews could have considered other topics, such as the affordability of backup energy systems as it relates to different types of houses and homeowners. Similarly, the interviews could have further honed in on understanding the possible benefits of solar PV and P2P energy trading systems that Nigerian consumers would be interested in and the preferences for different types of solar PV and P2P applications: Furthermore to inform the development of policy recommendations, the interviews could have considered the topic of government policies and incentives, particularly, to understand the impact of various policies and incentives on preferences for solar PV in Nigeria and how this can help to inform the design and deployment of solar PV systems.

The pilot survey received a low number of respondents (9), which affected efforts to generate priors that could have informed a more robust experimental design, as explained earlier. In hindsight, to mitigate this low turnout, I could have designed the pilot survey to include several estates, such that I would have been able to get a larger sample for the pilot.

On the DCE, using a D-efficient or Bayesian efficient experimental design might have improved the efficiency of the experimental design of the choice experiment. Three options were considered in determining the specific experimental design to use in this study. The Orthogonal design minimises correlations between attribute values to zero. The D-efficient design minimises all co-variances of all parameter estimates. The Sample efficient (s-efficient) design minimises the sample size needed to obtain statistically significant parameter estimates (Rose and Bliemer, 2009, 2013).

Recent developments in DCE design literature have shown that compared with the orthogonal design employed in this study, these 'efficient' designs offer more reliable parameter estimates when informed by prior information. The prior information can be based on existing literature or a pilot study with prior model estimates. However, the orthogonal method is most appropriate for studies without prior model estimates. Due to financial and logistical constraints at the time of designing the DCE, I could not afford the *Ngene* software, which is typically used in the literature to design D-efficient DCEs. After creating the DCE using the orthogonal method in R and administering the DCE, I became aware of free user-written commands in Stata, such as *dcreate* by

Hole (2017). Furthermore, although the DCE was piloted among a small sample of nine respondents in an estate in Ibadan, the initial model estimates derived were not so informative to inform the use of a D-efficient design. The Bayesian efficient design is another advanced design that could have been used in hindsight.

Another shortcoming of the DCE used in this study was the inability to include consistency checks. These involve the development of specific choice sets to check that the respondents' preferences exhibit specific theoretically desirable properties (Johnson et al., 2009; Varian, 1992). These properties include transitivity, monotonicity, stability and dominance. Tests for behaviour in line with these axioms could have been incorporated into the design of a DCE to check for its internal validity. Another limitation is also related to the backup attribute of the DCE, which included levels of ₦2m, when upfront prices for solar systems to power a standard two-bedroom home cost around ₦1m at the time, as seen in Section 5.3.1.

The survey responses could have also been affected by some self-selection bias, as people that attend estate meetings were more likely to complete the survey, and some confirmatory bias, as these respondents were likely to confirm the research hypotheses. However, to mitigate these biases, I have strived to be transparent about the selection process. A nationally representative sample might have increased the generalisability of the findings; however, logistical and financial constraints limited the study to just one city in Nigeria.

A larger pre-test of the survey would have improved the quality and reliability of the survey, as it would have been used to obtain more precise priors, which could have informed the use of a D-efficient design, and would have been a more efficient design option for the DCE. Similarly, the larger pre-test would have been helpful to further validate the survey instrument, including testing the wording and formatting of questions, as well as the overall structure and flow of the survey. The WTP analysis might have benefited from a comparative analysis such as the contingent valuation method.

On attribute selection, given the nascent nature of P2P energy trading, in hindsight, this study's P2P energy trading aspects might have benefited from a standalone DCE where preferences for specific attributes of P2P energy trading were investigated. This would have the study focus on other aspects of P2P energy trading beyond buying and selling, which were the levels of the energy trading attribute in the DCE. The study could have also possibly used a single cost attribute for simplicity purposes. Similarly, using a separate attribute for noise pollution and another for air pollution would have been useful to disentangle the effect of each of these types of pollution associated with the use of petrol and diesel generators.

The study could have also benefited from a further qualitative phase after the DCE. This qualitative phase could have involved focus groups or interviews, which would have been useful for further validating the survey results, such as the findings on the benefits of participating in P2P energy trading. The triangulation of the qualitative and quantitative data would have been useful in providing a more comprehensive answer to the research questions. Similarly, the survey could have benefited from member checking by comparing the results of the survey with the perceptions and experiences of the research participants. This would have helped to ensure that the findings accurately reflect the experiences and perspectives of the participants.

7.3.1. Reflections on the dichotomy between interest in buying and selling and system balance

A wider implication of this study is that it appears that the varying interests of different social groups in buying and selling energy could have various outcomes in terms of the balance of the system. As seen in this study, there are different social groups with varying interests in buying and selling energy, and these interests can have various outcomes on the electricity system. Some potential outcomes include the effects on demand for P2P energy trading and energy more broadly. For example, a group of residential customers may have different energy needs than a group of industrial customers, and this can impact the demand for P2P energy trading. Similarly, various social groups may have different financial resources and incentives to invest in renewable energy sources, which can affect the adoption of renewable energy technologies. Wealthy individuals may be more likely to invest in solar panels than a group of low-income individuals, which can impact the overall adoption of renewable energy and participation in P2P energy trading. Furthermore, there might be different social groups with varying political power and influence, which can affect energy policy and regulation as it relates to P2P energy trading. Thus, the varying interests of different social groups in buying and selling energy can have complex and multifaceted impacts on the electricity system, and it is important to consider the needs and interests of all stakeholders in order to ensure a fair and effective P2P energy trading system.

Another emergent issue from this study seems to be that selling energy into the grid needs to become more attractive. The attractiveness of selling excess electricity to the grid will depend on a combination of economic, technological, and policy factors. On the economic factors, there is a need for financial incentives to make selling attractive. Governments and utilities may offer financial incentives, such as feed-in tariffs or net metering, to encourage individuals to sell excess electricity to the grid. These incentives can help to offset the costs of producing and selling electricity and make it more financially attractive for individuals to participate. On the technological side, there is a need for improved grid infrastructure, such as the need for smart meters that allow for two-way communication. Smart meters that are designed for two-way interaction can provide flexibility benefits compared to traditional meters that only allow one-way communication. The reliability of grid infrastructure capable of handling excess electricity can make it more attractive for individuals to sell excess electricity to the grid. On the policy side, as outlined above, government policies that support the adoption of renewable energy, such as subsidies or tax credits, can make it more attractive for individuals to sell excess electricity to the grid. By addressing these factors, stakeholders in the energy sector, such as policymakers and utilities, can help to make it more attractive for individuals to sell excess electricity to the grid.

7.4. Agenda for future research

Whilst this study has presented evidence on the preferences of residential electricity consumers in estates to use clean & quiet forms of backup electricity, notably solar PV and interest in P2P trading of energy, there is a need for further complementary work to encourage the development of clean, quiet residential estates. This can include further studies and consultations by real estate developers and estate associations on improvements to local estate regulations and changes to lease agreements to make such clean estates attractive to prospective homeowners.

The DCE literature would also benefit from more nuanced studies from developing countries to help inform priors. This can aid in better DCE design for researchers and practitioners in developing countries that might be resource constrained, with developing efficient DCEs, which are often time and resource intensive. Furthermore, given that energy access is still an important policy issue in Africa, other studies can apply DCEs in the areas of energy access and affordability. Such DCEs could be used to understand how people in Africa make decisions about energy access and affordability, including choices between different types of energy sources and different levels of service. This could help policymakers and utilities to design more effective and equitable energy access programs. Furthermore, given the important role that energy storage would plan in facilitating increased adoption of renewables and P2P energy trading, other studies can examine the use of DCEs to understand how people in Africa and other developing countries would make decisions about energy storage and distribution, including choices between different technologies and strategies for managing the grid. This can inform the estimates of willingness to pay for energy storage and help policymakers and utilities to design more efficient and reliable energy systems.

To advance P2P energy trading, further research on the economic, legal, regulatory and technological aspects of P2P energy trading is needed in Nigeria. Further research could examine if residents will still be keen on buying energy from a P2P platform managed by an estate developer. Researchers can also explore the scope for adjustments to Nigeria's feed-in tariff for renewables to accommodate P2P energy trading aspects and identify legal instruments that can be used to incentivise participation further. The viability of a P2P energy trading system is dependent on having enough participants willing to trade electricity. Therefore, estimates of WTP for P2P energy trading in Nigeria are an area that can be explored further. Researchers can also evaluate the appropriateness of various technology platforms (e.g., blockchain) for P2P energy trading in this context.

Furthermore, other studies can expand on the assessment of underlying motivations and values that drive autarky preferences for P2P energy trading by considering the use of experimental economic games among homeowners in developing countries like Nigeria to test the preferences of individuals for self-sufficiency and trade. This would expand on the findings of the literature review identified in Section 2.2 on the limited nature of real-world applications. The experimental games with homeowners (rather than simulations, or students, as is the case with many of these games) can be useful to identify the conditions under which individuals or groups are more or less likely to prefer autarky. Results from such games can also inform economic modelling to simulate the effects of different P2P trading scenarios for individuals or levels of self-sufficiency on homeowners' energy supply. Such modelling work can help to identify the costs and benefits of different levels of autarky and inform household decision-making. Finally, other studies can examine temporal aspects of P2P energy trading, mainly how preferences for P2P energy trading in Nigeria might vary at different times of the year. Such research can include exploring seasonal variations in potential trading patterns, e.g., during the rainy season, where lower solar radiation is expected, versus the dry season, where higher solar radiation can be expected.

7.5. Conclusion

In summary, this thesis has focused on the personal benefits of a clean local environment that solar energy can provide. The thesis findings that consumers are interested in dwelling in estates that only permit cleaner backup alternatives, including solar and inverters, compared with the status quo option of dwelling in estates with petrol or diesel generators. This reveals an opportunity to develop and market clean, quiet estates that appeal to people concerned about the health impacts of generator use. The study also finds that consumers are interested in P2P energy trading, with differences in preferences for selling and buying excess electricity from neighbours. Furthermore, the thesis also finds that autarky aspirations and financial benefits are key factors that influence participation in energy trading.

REFERENCES

Abdullah *et al.* (2017) 'Acceptance and willingness to pay for solar home system: Survey evidence from northern area of Pakistan', *Energy Reports*. Elsevier, 3, pp. 54–60. doi: 10.1016/J.EGYR.2017.03.002.

Abdullah, S. and Jeanty, P. W. (2011) 'Willingness to pay for renewable energy: Evidence from a contingent valuation survey in Kenya', *Renewable and Sustainable Energy Reviews*, 15(6), pp. 2974–2983. doi: https://doi.org/10.1016/j.rser.2011.03.016.

Ableitner, L. *et al.* (2020) 'User behavior in a real-world peer-to-peer electricity market', *Applied Energy*. Elsevier Ltd, 270. doi: 10.1016/j.apenergy.2020.115061.

Adams, S. *et al.* (2021) 'Social and Economic Value in Emerging Decentralized Energy Business Models: A Critical Review', *Energies 2021, Vol. 14, Page 7864*. Multidisciplinary Digital Publishing Institute, 14(23), p. 7864. doi: 10.3390/EN14237864.

Adedeji, A. A. (2016) *Spatial Exploration and Analysis of Electricity Poverty: A Case Study of Ibadan, Southwestern, Nigeria*. University of Leicester. Available at: https://lra.le.ac.uk/bitstream/2381/37461/1/2016ADEDEJIAAPhD.pdf.

Adeleke, A. T. *et al.* (2022) 'Household Poverty Status and Willingness to Pay for Renewable Energy Technologies: Evidence from Southwestern Nigeria', in *Environmental Sciences Proceedings 2022, Vol. 15, Page 3*. Multidisciplinary Digital Publishing Institute, p. 3. doi: 10.3390/environsciproc2022015003.

Adenikinju, A. (2005) 'Analysis of the cost of infrastructure failures in a developing economy: The case of the electricity sector in Nigeria.', *AERC Research Papers Series*. African Economic Research Consortium, Nairobi, 2(February), pp. 1–38. Available at: https://www.africaportal.org/documents/5651/RP148.pdf%0A.

Adenle, A. A. (2020) 'Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals', *Energy Policy*. Elsevier, 137, p. 111180.

Adeoti, O., Oyewole, B. A. and Adegboyega, T. D. (2001) 'Solar photovoltaic-based home electrification system for rural development in Nigeria: domestic load assessment', *Renewable Energy*. Pergamon, 24(1), pp. 155–161. doi: 10.1016/S0960-1481(00)00188-9.

Adetokun, B. B., Ojo, J. O. and Muriithi, C. M. (2021) 'Application of large-scale grid-connected solar photovoltaic system for voltage stability improvement of weak national grids', *Scientific Reports*. Nature Publishing Group, 11(1), pp. 1–15.

Adurodija, F. ., Asia, I. . and Chendo, M. A. . (1998) 'The market potential of photovoltaic systems in Nigeria', *Solar Energy*. Pergamon, 64(4–6), pp. 133–139. doi: 10.1016/S0038-092X(98)00095-4.

Agnew, S. and Dargusch, P. (2017) ‘Consumer preferences for household-level battery energy storage’, *Renewable and Sustainable Energy Reviews*. Pergamon, 75, pp. 609–617. doi: 10.1016/J.RSER.2016.11.030.

Aguilar, F. X. and Vlosky, R. P. (2007) ‘Consumer willingness to pay price premiums for environmentally certified wood products in the U.S.’, *Forest Policy and Economics*, 9(8), pp. 1100–1112. doi: 10.1016/j.forpol.2006.12.001.

Aizaki, H. (2015) *Package ‘support.CEs’ Titled Basic Functions for Supporting an Implementation of Choice Experiments*. Available at: https://cran.r-project.org/web/packages/support.CEs/support.CEs.pdf.

Aizaki, H., Nakatani, T. and Sato, K. (2014) *Stated preference methods using R*. 1st Editio. Chapman and Hall/CRC. Available at: https://www.crcpress.com/Stated-Preference-Methods-Using-R/Aizaki-Nakatani-Sato/p/book/9781439890479.

Aizaki, H. and Nishimura, K. (2008) *Design and Analysis of Choice Experiments Using R: A Brief Introduction*, *Agricultural Information Research*. Available at: www.jstage.jst.go.jp/.

Alao, T. (2018) ‘Lagos residents at war over generator noise’, *Tribune Newspaper*, 2 June. Available at: https://www.tribuneonlineng.com/148683/.

Alberini, A. *et al.* (2018) ‘Preferences for Energy Efficiency vs. Renewables: What Is the Willingness to Pay to Reduce CO2 Emissions?’, *Ecological Economics*. Elsevier, 144, pp. 171–185. doi: 10.1016/J.ECOLECON.2017.08.009.

Alem, Y. *et al.* (2016) ‘Modeling household cooking fuel choice: A panel multinomial logit approach’, *Energy Economics*, 59(Supplement C), pp. 129–137. doi: https://doi.org/10.1016/j.eneco.2016.06.025.

de Almeida, L. *et al.* (2021) *Peer-to-peer trading and energy community in the electricity market: analysing the literature on law and regulation and looking ahead to future challenges*. International Energy Agency.

Andoni, M. *et al.* (2019) ‘Blockchain technology in the energy sector: A systematic review of challenges and opportunities’, *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, pp. 143–174. doi: 10.1016/j.rser.2018.10.014.

Andor, M. A., Frondel, M. and Sommer, S. (2018) ‘Equity and the willingness to pay for green electricity in Germany’, *Nature Energy*. Nature Publishing Group, 3(10), pp. 876–881. doi: 10.1038/s41560-018-0233-x.

Andor, M. A., Frondel, M. and Vance, C. (2017) ‘Germany’s Energiewende: A Tale of Increasing Costs and Decreasing Willingness-To-Pay’, *The Energy Journal*. International Association for Energy Economics, 38(01). doi: 10.5547/01956574.38.SI1.mand.

Anugwom, E. E. (2022) ‘Solar Home Systems in Rural Landscapes: Examining the Forces Shaping Solar Home Systems Adoption in Southeast Nigeria’, in *Off-Grid Solar*

Electrification in Africa. Springer, pp. 287–313.

Arawomo, D. F. (2017) ‘Electricity billing systems and household electricity use behaviour in Ibadan, Nigeria’, *Energy for Sustainable Development*. Elsevier B.V., 40, pp. 77–84. doi: 10.1016/j.esd.2017.07.004.

Arega, T. and Tadesse, T. (2017) ‘Household willingness to pay for green electricity in urban and peri-urban Tigray, northern Ethiopia: Determinants and welfare effects’, *Energy Policy*. Elsevier, 100, pp. 292–300. doi: 10.1016/J.ENPOL.2016.10.022.

Awofeso, N. (2011) ‘Generator Diesel Exhaust: a Major Hazard to Health and the Environment in Nigeria’, *American Journal of Respiratory and Critical Care Medicine*. American Thoracic Society, 183(10), pp. 1437–1437. doi: 10.1164/ajrccm.183.10.1437.

Ayodele, T. R. *et al.* (2021) ‘Willingness to pay for green electricity derived from renewable energy sources in Nigeria’, *Renewable and Sustainable Energy Reviews*, 148, p. 111279. doi: 10.1016/j.rser.2021.111279.

Ayodele, T. R., Ogunjuyigbe, A. S. O. and Nwakanma, K. C. (2021) ‘Solar energy harvesting on building’s rooftops: A case of a Nigeria cosmopolitan city’, *Renewable Energy Focus*. Elsevier, 38, pp. 57–70. doi: 10.1016/J.REF.2021.06.001.

Babajide, A. and Brito, M. C. (2021) ‘Solar PV systems to eliminate or reduce the use of diesel generators at no additional cost: A case study of Lagos, Nigeria’, *Renewable Energy*. Pergamon, 172, pp. 209–218. doi: 10.1016/J.RENENE.2021.02.088.

Balcombe, P., Rigby, D. and Azapagic, A. (2014) ‘Investigating the importance of motivations and barriers related to microgeneration uptake in the UK’. doi: 10.1016/J.APENERGY.2014.05.047.

Bao, Q. *et al.* (2020) ‘A human-centered design approach to evaluating factors in residential solar PV adoption: A survey of homeowners in California and Massachusetts’, *Renewable Energy*, 151, pp. 503–513. doi: 10.1016/j.renene.2019.11.047.

Battaglia, M. P. (2014) ‘Encyclopedia of Survey Research Methods Nonprobability Sampling’. doi: 10.4135/9781412963947.n337.

Bauwens, T. (2019) ‘Analyzing the determinants of the size of investments by community renewable energy members: Findings and policy implications from Flanders’, *Energy Policy*, 129, pp. 841–852. doi: 10.1016/j.enpol.2019.02.067.

Bazilian, M. *et al.* (2012) ‘Energy access scenarios to 2030 for the power sector in sub-Saharan Africa’, *Utilities Policy*, 20(1), pp. 1–16. doi: https://doi.org/10.1016/j.jup.2011.11.002.

Bech, M. and Gyrd-Hansen, D. (2005) ‘Effects coding in discrete choice experiments’, *Health Economics*, 14(10), pp. 1079–1083. doi: 10.1002/hec.984.

Bellekom, S., Arentsen, M. and van Gorkum, K. (2016) ‘Prosumption and the distribution and supply of electricity’, *Energy, Sustainability and Society*, 6(1). doi: 10.1186/s13705-016-0087-7.

Ben-Akiva, M. E. and Lerman, S. R. (1985) *Discrete choice analysis: theory and application to travel demand*. MIT press.

Benbrahim-Tallaa, L. *et al.* (2012) ‘Carcinogenicity of diesel-engine and gasoline-engine exhausts and some nitroarenes.’, *The Lancet. Oncology*. Elsevier, 13(7), pp. 663–4. doi: 10.1016/S1470-2045(12)70280-2.

Bergek, A. and Mignon, I. (2017) ‘Motives to adopt renewable electricity technologies: Evidence from Sweden’, *Energy Policy*, 106, pp. 547–559. doi: 10.1016/j.enpol.2017.04.016.

Bigerna, S. and Polinori, P. (2014) ‘Italian households′ willingness to pay for green electricity’, *Renewable and Sustainable Energy Reviews*. Pergamon, 34, pp. 110–121. doi: 10.1016/J.RSER.2014.03.002.

Black, T. R. (1999) *Doing quantitative research in the social sciences: An integrated approach to research design, measurement and statistics*. Sage.

Bliemer, M. C. J., Rose, J. M. and Chorus, C. G. (2017) ‘Detecting dominance in stated choice data and accounting for dominance-based scale differences in logit models’, *Transportation Research Part B: Methodological*, 102. doi: 10.1016/j.trb.2017.05.005.

Blimpo, M. P. and Cosgrove-Davies, M. (2019) *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact*, *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact*. doi: 10.1596/978-1-4648-1361-0.

Blimpo, M. P., Postepska, A. and Xu, Y. (2020) ‘Why is household electricity uptake low in Sub-Saharan Africa?’, *World Development*. Elsevier, 133, p. 105002.

Bloomberg New Energy Finance (2017) *New Energy Outlook 2017*. Available at: https://about.bnef.com/new-energy-outlook/#toc-download.

Bloomberg New Energy Finance (2020) *Scale-up of Solar and Wind Puts Existing Coal, Gas at Risk | BloombergNEF*. Available at: https://about.bnef.com/blog/scale-up-of-solar-and-wind-puts-existing-coal-gas-at-risk/.

Bollinger, B. and Gillingham, K. (2012) ‘Peer Effects in the Diffusion of Solar Photovoltaic Panels’, *Marketing Science*, 31(6), pp. 900–912. doi: 10.1287/mksc.1120.0727.

Bondio, S., Shahnazari, M. and McHugh, A. (2018) ‘The technology of the middle class: Understanding the fulfilment of adoption intentions in Queensland’s rapid uptake residential solar photovoltaics market’, *Renewable and Sustainable Energy Reviews*, 93, pp. 642–651. doi: 10.1016/j.rser.2018.05.035.

Borchers, A. M., Duke, J. M. and Parsons, G. R. (2007) ‘Does willingness to pay for green energy differ by source?’, *Energy Policy*. Elsevier, 35(6), pp. 3327–3334. doi: 10.1016/J.ENPOL.2006.12.009.

Boxall, P. C. and Adamowicz, W. L. (2002) ‘Understanding heterogeneous preferences in random utility models: a latent class approach’, *Environmental and resource economics*. Springer, 23(4), pp. 421–446.

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

Breidert, C., Hahsler, M. and Reutterer, T. (2015) *A Review of Methods for Measuring Willingness-to-Pay*, *Innovative Marketing*.

Bridges, J. F. P. *et al.* (2011) ‘Conjoint Analysis Applications in Health—a Checklist: A Report of the ISPOR Good Research Practices for Conjoint Analysis Task Force’, *Value in Health*. Elsevier, 14(4), pp. 403–413. doi: 10.1016/J.JVAL.2010.11.013.

Briguglio, M. and Formosa, G. (2017) ‘When households go solar: Determinants of uptake of a Photovoltaic Scheme and policy insights’, *Energy Policy*, 108, pp. 154–162. doi: 10.1016/j.enpol.2017.05.039.

Bronski, P. *et al.* (2014) ‘The economics of grid defection’. Boulder, CO: Rocky Mountain Institute. Available at: https://www.ourenergypolicy.org/wp-content/uploads/2014/02/RMIGridDefectionFull_2014-05.pdf.

Brook, R. D. *et al.* (2010) ‘Particulate Matter Air Pollution and Cardiovascular Disease’, *Circulation*, 121(21), pp. 2331–2378. doi: 10.1161/CIR.0b013e3181dbece1.

Broto, V. C. *et al.* (2017) ‘A research agenda for a people-centred approach to energy access in the urbanizing global south’, *Nature Energy*, 2(10), pp. 776–779. doi: 10.1038/s41560-017-0007-x.

Brown, D., Hall, S. and Davis, M. E. (2019) ‘Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK’, *Energy Policy*. Elsevier, 135, p. 110984. doi: 10.1016/J.ENPOL.2019.110984.

Brown, M., Woodhouse, S. and Sioshansi, F. (2019) *Digitalization of energy*, *Consumer, Prosumer, Prosumager: How Service Innovations will Disrupt the Utility Business Model*. Elsevier Inc. doi: 10.1016/B978-0-12-816835-6.00001-2.

Brummer, V. (2018) ‘Community energy–benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces’, *Renewable and Sustainable Energy Reviews*. Elsevier, 94, pp. 187–196.

Bryman, A. (2008) *Social research methods*. 3rd edn. Oxford: Oxford University Press.

Buba, J. *et al.* (2016) *An assessment of the investment climate in Nigeria : the challenges of Nigeria’s private sector*. ACS15736. Washington, D.C. Available at:

http://documents.worldbank.org/curated/en/641551481520950285/Main-report.

Bugaje, I. . (1999) 'Remote area power supply in Nigeria: the prospects of solar energy', *Renewable Energy*. Pergamon, 18(4), pp. 491–500. doi: 10.1016/S0960-1481(98)00814-3.

Bull, J. (2012) 'Loads of green washing-can behavioural economics increase willingness-to-pay for efficient washing machines in the UK?', *Energy Policy*. Elsevier, 50, pp. 242–252. doi: 10.1016/j.enpol.2012.07.001.

Byrnes, B., Jones, C. and Goodman, S. (1999) 'Contingent valuation and real economic commitments: Evidence from electric utility green pricing programmes', *Journal of Environmental Planning and Management*, 42(2), pp. 149–166. doi: 10.1080/09640569911190.

Calfee, J., Winston, C. and Stempski, R. (2001) 'Econometric issues in estimating consumer preferences from stated preference data: A case study of the value of automobile travel time', *Review of Economics and Statistics*, 83(4), pp. 699–707. doi: 10.1162/003465301753237777.

Cardella, E., Ewing, B. T. and Williams, R. B. (2017) 'Price volatility and residential electricity decisions: Experimental evidence on the convergence of energy generating source', *Energy Economics*. North-Holland, 62, pp. 428–437. doi: 10.1016/J.ENECO.2016.07.012.

Carley, S. and Konisky, D. M. (2020) 'The justice and equity implications of the clean energy transition', *Nature Energy*. Nature Publishing Group, 5(8), pp. 569–577.

Carlisle, J. E. *et al.* (2015) 'Public attitudes regarding large-scale solar energy development in the U.S.', *Renewable and Sustainable Energy Reviews*. Pergamon, 48, pp. 835–847. doi: 10.1016/J.RSER.2015.04.047.

Carlsson, F. and Martinsson, P. (2008) 'Does it matter when a power outage occurs?—A choice experiment study on the willingness to pay to avoid power outages', *Energy Economics*. Elsevier, 30(3), pp. 1232–1245.

Carson, R. T., Flores, N. E. and Meade, N. F. (2001) 'Contingent valuation: Controversies and evidence', *Environmental and Resource Economics*, 19(2), pp. 173–210. doi: 10.1023/A:1011128332243.

Casey, J. F., Kahn, J. R. and Rivas, A. A. F. (2008) 'Willingness to accept compensation for the environmental risks of oil transport on the Amazon: A choice modeling experiment', *Ecological Economics*. Elsevier, 67(4), pp. 552–559. doi: 10.1016/J.ECOLECON.2008.01.006.

Champ, P. A., Boyle, K. J. and Brown, T. C. (2017) *The Economics of Non-Market Goods and Resources: A Primer on Nonmarket Valuation*. Second Edi, *Springer*. Second Edi. Available at: http://link.springer.com/10.1007/978-94-007-7104-8.

Chen, H. Q., Honda, T. and Yang, M. C. (2013) 'Approaches for Identifying Consumer

Preferences for the Design of Technology Products: A Case Study of Residential Solar Panels', *Journal of Mechanical Design*, 135(6), p. 061007. doi: 10.1115/1.4024232.

Cheng, Y. S. *et al.* (2017) 'Residential willingness to pay for deep decarbonization of electricity supply: Contingent valuation evidence from Hong Kong', *Energy Policy*. Elsevier, 109, pp. 218–227. doi: 10.1016/J.ENPOL.2017.07.006.

Child, M. *et al.* (2019) 'Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe', *Renewable energy*. Elsevier, 139, pp. 80–101.

Clark, M. D. *et al.* (2014) 'Discrete Choice Experiments in Health Economics: A Review of the Literature', *PharmacoEconomics*. Springer International Publishing, 32(9), pp. 883–902. doi: 10.1007/s40273-014-0170-x.

Climate Action Tracker (2021) *Nigeria Net zero targets - Climate Action Tracker*. Available at: https://climateactiontracker.org/countries/nigeria/net-zero-targets/.

Coast, J. *et al.* (2012) 'Using qualitative methods for attribute development for discrete choice experiments: issues and recommendations', *Health Economics*. Wiley-Blackwell, 21(6), pp. 730–741. doi: 10.1002/hec.1739.

Coast, J. and Horrocks, S. (2007) 'Developing attributes and levels for discrete choice experiments using qualitative methods', *Journal of Health Services Research & Policy*. SAGE PublicationsSage UK: London, England, 12(1), pp. 25–30. doi: 10.1258/135581907779497602.

Contejean, A. and Verin, L. (2017) *Making mini-grids work: Productive uses of electricity in Tanzania*. Available at: http://pubs.iied.org/16632IIED/.

Creswell, J. W. (2014) *Research design: Qualitative, quantitative, and mixed method*. 4th edn, *Research design: Qualitative quantitative and mixed methods approaches*. 4th edn. SAGE Publications Ltd.

Dagher, L. and Harajli, H. (2015) 'Willingness to pay for green power in an unreliable electricity sector: Part 1. The case of the Lebanese residential sector', *Renewable and Sustainable Energy Reviews*. Pergamon, 50, pp. 1634–1642. doi: 10.1016/J.RSER.2015.04.162.

Dahunsi, F. M., Olakunle, O. R. and Melodi, A. O. (2021) 'Evolution of Electricity Metering Technologies in Nigeria', *Nigerian Journal of Technological Development*, 18(2), pp. 152–165.

Daily Trust (2007) 'Nigeria: MTN Spends N660 Million On Diesel Monthly', *Daily Trust*, 6 December. Available at: http://allafrica.com/stories/200712060399.html.

Daly, A., Dekker, T. and Hess, S. (2016) 'Dummy coding vs effects coding for categorical variables: Clarifications and extensions', *Journal of Choice Modelling*, 21. doi: 10.1016/j.jocm.2016.09.005.

Dellaert, B. G. C., Donkers, B. and Van Soest, A. (2012) ‘Complexity Effects in Choice Experiment–Based Models’, *Journal of Marketing Research*. SAGE PublicationsSage CA: Los Angeles, CA, 49(3), pp. 424–434. doi: 10.1509/jmr.09.0315.

DeShazo, J. R. and Fermo, G. (2002) ‘Designing choice sets for stated preference methods: The effects of complexity on choice consistency’, *Journal of Environmental Economics and Management*. Elsevier, 44(1), pp. 123–143. doi: 10.1006/jeem.2001.1199.

‘Discrete Choice Experiments: A Guide to Model Specification, Estimation and Software’ (2017) *PharmacoEconomics*, 35(7). doi: 10.1007/s40273-017-0506-4.

Ecker, F., Hahnel, U. J. J. and Spada, H. (2017) ‘Promoting Decentralized Sustainable Energy Systems in Different Supply Scenarios: The Role of Autarky Aspiration’, *Frontiers in Energy Research*. Frontiers, 0(JUL), p. 14. doi: 10.3389/FENRG.2017.00014.

Ecker, F., Spada, H. and Hahnel, U. J. J. (2018) ‘Independence without control: Autarky outperforms autonomy benefits in the adoption of private energy storage systems’, *Energy Policy*. Elsevier Ltd, 122, pp. 214–228. doi: 10.1016/j.enpol.2018.07.028.

Einav, L., Farronato, C. and Levin, J. (2016) ‘Peer-to-Peer Markets’, *Annual Review of Economics*. Annual Reviews, 8(1), pp. 615–635. doi: 10.1146/annurev-economics-080315-015334.

Elegbede, O. *et al.* (2021) ‘Using a choice experiment to understand preferences in off-grid solar electricity attributes: The case of Nigerian households’, *Energy for Sustainable Development*. Elsevier B.V., 60, pp. 33–39. doi: 10.1016/j.esd.2020.12.001.

Engelken, M. *et al.* (2018) ‘Why homeowners strive for energy self-supply and how policy makers can influence them’, *Energy Policy*. Elsevier, 117, pp. 423–433. doi: 10.1016/J.ENPOL.2018.02.026.

Eslamizadeh, S. *et al.* (2020) ‘Can industries be parties in collective action? Community energy in an Iranian industrial zone’, *Energy Research & Social Science*. Elsevier, 70, p. 101763. doi: 10.1016/J.ERSS.2020.101763.

Esmat, A. *et al.* (2021) ‘A novel decentralized platform for peer-to-peer energy trading market with blockchain technology’, *Applied Energy*. Elsevier, 282, p. 116123. doi: 10.1016/J.APENERGY.2020.116123.

Fares, R. L. and Webber, M. E. (2017) ‘The impacts of storing solar energy in the home to reduce reliance on the utility’, *Nature Energy 2017 2:2*. Nature Publishing Group, 2(2), pp. 1–10. doi: 10.1038/nenergy.2017.1.

Fateye, T. B. *et al.* (2021) ‘Basic residential neighborhood infrastructure financing in Nigeria urban cities: Community development associations (CDAs)-based approach’, *Journal of Infrastructure, Policy and Development*. EnPress Publisher, LLC, 5(1), p. 1242. doi: 10.24294/JIPD.V5I1.1242.

Federal Government of Nigeria (FGN) (2016) ‘Sustainable Energy for All Action Agenda (SE4ALL-AA) for Nigeria’. Abuja. Available at: https://www.seforall.org/sites/default/files/NIGERIA_SE4ALL_ACTION_AGENDA_FINAL.pdf.

Federal Government of Nigeria (FGN) (2021) *Nigeria’s Nationally Determined Contribution*. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Nigeria First/NIGERIA 2021 NDC-FINAL.pdf.

Fell, M. J., Schneiders, A. and Shipworth, D. (2019) ‘Consumer Demand for Blockchain-Enabled Peer-to-Peer Electricity Trading in the United Kingdom: An Online Survey Experiment’, *Energies 2019, Vol. 12, Page 3913*. Multidisciplinary Digital Publishing Institute, 12(20), p. 3913. doi: 10.3390/EN12203913.

Franke, M. and Nadler, C. (2019) ‘Energy efficiency in the German residential housing market: Its influence on tenants and owners’, *Energy Policy*. Elsevier Ltd, 128(January), pp. 879–890. doi: 10.1016/j.enpol.2019.01.052.

Freeman, A. M. (2003) ‘Economic Valuation: What and Why’, in, pp. 1–25. doi: 10.1007/978-94-007-0826-6_1.

Gährs, S. *et al.* (2015) ‘Acceptance of Ancillary Services and Willingness to Invest in PV-storage-systems’, *Energy Procedia*. Elsevier, 73, pp. 29–36. doi: 10.1016/J.EGYPRO.2015.07.554.

Gamel, J., Menrad, K. and Decker, T. (2016) ‘Is it really all about the return on investment? Exploring private wind energy investors’ preferences’, *Energy Research & Social Science*. Elsevier, 14, pp. 22–32. doi: 10.1016/J.ERSS.2016.01.004.

Garces-Voisenat, J.-P. and Mukherjee, Z. (2016) ‘Paying for green energy: The case of the Chilean Patagonia’, *Journal of Policy Modeling*. North-Holland, 38(2), pp. 397–414. doi: 10.1016/J.JPOLMOD.2016.03.012.

Georgarakis, E. *et al.* (2021) ‘Keep it green, simple and socially fair: A choice experiment on prosumers’ preferences for peer-to-peer electricity trading in the Netherlands’, *Energy Policy*. Elsevier, 159, p. 112615. doi: 10.1016/J.ENPOL.2021.112615.

Ghijben, P., Lancsar, E. and Zavarsek, S. (2014) ‘Preferences for Oral Anticoagulants in Atrial Fibrillation: a Best–Best Discrete Choice Experiment’, *PharmacoEconomics*. Springer International Publishing, 32(11), pp. 1115–1127. doi: 10.1007/s40273-014-0188-0.

Ghosh, R. *et al.* (2017) ‘Are small firms willing to pay for improved power supply? Evidence from a contingent valuation study in India’, *Energy Policy*. Elsevier, 109, pp.

659–665. doi: 10.1016/J.ENPOL.2017.07.046.

Giwa, S. O., Nwaokocha, C. N. and Adeyemi, H. O. (2019) ‘Noise and emission characterization of off-grid diesel-powered generators in Nigeria’, *Management of Environmental Quality: An International Journal*, 30(4), pp. 783–802. doi: 10.1108/MEQ-07-2018-0120.

Glumac, B. and Wissink, T. P. (2018) ‘Homebuyers’ preferences concerning installed photovoltaic systems’, *Journal of European Real Estate Research*, 11(1), pp. 102–124. doi: 10.1108/JERER-12-2016-0044.

Goedkoop, F. and Devine-Wright, P. (2016) ‘Partnership or placation? The role of trust and justice in the shared ownership of renewable energy projects’, *Energy Research & Social Science*. Elsevier, 17, pp. 135–146. doi: 10.1016/J.ERSS.2016.04.021.

GOGLA (2021) *Global Off-Grid Solar Market Report | GOGLA*. Available at: https://www.gogla.org/global-off-grid-solar-market-report.

Graber, S. *et al.* (2018) ‘Solar microgrids in rural India: Consumers’ willingness to pay for attributes of electricity’, *Energy for Sustainable Development*. International Energy Initiative, 42(Supplement C), pp. 32–43. doi: https://doi.org/10.1016/j.esd.2017.10.002.

Greene, W. H. and Hensher, D. A. (2003) ‘A latent class model for discrete choice analysis: contrasts with mixed logit’, *Transportation Research Part B: Methodological*, 37(8), pp. 681–698. doi: 10.1016/S0191-2615(02)00046-2.

Greene, W. H. and Hensher, D. A. (2013) ‘Revealing additional dimensions of preference heterogeneity in a latent class mixed multinomial logit model’, *Applied Economics*. doi: 10.1080/00036846.2011.650325.

Grimm, M. *et al.* (2017) ‘A first step up the energy ladder? Low cost solar kits and household’s welfare in rural Rwanda’, *World Bank Economic Review*. Oxford University Press, 31(3), pp. 631–649. doi: 10.1093/wber/lhw052.

Guba, E. G. and Lincoln, Y. S. (1994) ‘Competing paradigms in qualitative research’, *Handbook of qualitative research*. Sage, Thousand Oaks, CA, 2(163–194), p. 105.

Gudeman, S. F. (2001) *The Anthropology of Economy*. 1st edn. Oxford: Blackwell Publishers Inc.

Gudeman, S. F. (2008) *Economy’s tension: the dialectics of community and market*. Berghahn Books.

Gudeman, S. F. (2016) *Anthropology and Economy*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781316442739.

Gulati, K. (2010) ‘Effects of diesel exhaust, heavy metals and pesticides on various organ systems: Possible mechanisms and strategies for prevention and treatment’, *Indian Journal of Experimental Biology*, pp. 710–721.

Gunarathna, C. L. *et al.* (2022) 'Reviewing global peer-to-peer distributed renewable energy trading projects', *Energy Research & Social Science*. Elsevier, 89, p. 102655.

Guo, X. *et al.* (2014) 'Willingness to pay for renewable electricity: A contingent valuation study in Beijing, China', *Energy Policy*. Elsevier, 68(Supplement C), pp. 340–347. doi: https://doi.org/10.1016/j.enpol.2013.11.032.

Hackbarth, A. and Löbbe, S. (2020) 'Attitudes, preferences, and intentions of German households concerning participation in peer-to-peer electricity trading', *Energy Policy*. Elsevier Ltd, 138, p. 111238. doi: 10.1016/j.enpol.2020.111238.

Hackbarth, A. and Madlener, R. (2016) 'Willingness-to-pay for alternative fuel vehicle characteristics: A stated choice study for Germany', *Transportation Research Part A: Policy and Practice*. Pergamon, 85, pp. 89–111. doi: 10.1016/J.TRA.2015.12.005.

Hahnel, U. J. J. *et al.* (2020) 'Becoming prosumer: Revealing trading preferences and decision-making strategies in peer-to-peer energy communities', *Energy Policy*. Elsevier Ltd, 137, p. 111098. doi: 10.1016/j.enpol.2019.111098.

Halcomb, E. and Hickman, L. (2015) 'Mixed methods research', *Nursing Standard*, 29(32), pp. 41–47. doi: 10.7748/ns.29.32.41.e8858.

Hanley, N., Mourato, S. and Wright, R. E. (2001) 'Choice modelling approaches: A superior alternative for environmental valuation?', *Journal of Economic Surveys*. doi: 10.1111/1467-6419.00145.

Hanser, P. *et al.* (2017) 'The practicality of distributed PV-battery systems to reduce household grid reliance', *Utilities Policy*. Pergamon, 46, pp. 22–32. doi: 10.1016/J.JUP.2017.03.004.

Health Effects Institute (HEI) (2018) *State of Global Air 2018: A Special Report On Global Exposure to Air Pollution and Its Disease Burden*. Boston. Available at: https://www.stateofglobalair.org/sites/default/files/soga-2018-report.pdf.

Heinemann, G. *et al.* (2022) 'Transforming electricity access by replacing back-up generators with solar systems: Recent trends and evidence from Nigeria', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 157. doi: 10.1016/J.RSER.2021.111751.

Hensher, D. A. (2010) 'Hypothetical bias, choice experiments and willingness to pay', *Transportation Research Part B: Methodological*. Pergamon, 44(6), pp. 735–752. doi: 10.1016/J.TRB.2009.12.012.

Hensher, D. A., Rose, J. M. and Greene, W. H. (2005) *Applied choice analysis: A primer*, *Applied Choice Analysis: A Primer*. Cambridge University Press. doi: 10.1017/CBO9780511610356.

Hensher, D. A., Rose, J. M. and Greene, W. H. (2015) *Applied choice analysis*, *Applied Choice Analysis*. Cambridge University Press. doi: 10.1007/9781316136232.

Hensher, D. A., Shore, N. and Train, K. (2014) ‘Willingness to pay for residential electricity supply quality and reliability’, *Applied Energy*. Elsevier, 115, pp. 280–292. doi: 10.1016/J.APENERGY.2013.11.007.

Herbes, C. *et al.* (2015) ‘Willingness to pay lip service? Applying a neuroscience-based method to WTP for green electricity’, *Energy Policy*. Elsevier, 87, pp. 562–572. doi: 10.1016/J.ENPOL.2015.10.001.

Hess, S. and Daly, A. (2014) *Handbook of Choice Modelling*. Edited by S. Hess and A. Daly. Cheltenham, UK: Edward Elgar Publishing. doi: https://doi.org/10.4337/9781781003152.00005.

Hole, A. (2017) ‘DCREATE: Stata module to create efficient designs for discrete choice experiments’. Boston College Department of Economics.

Howells, M. I. *et al.* (2005) ‘A model of household energy services in a low-income rural African village’, *Energy Policy*. Elsevier, 33(14), pp. 1833–1851. doi: 10.1016/J.ENPOL.2004.02.019.

Hutcheson, G. D. and Sofroniou, N. (1999) *The multivariate social scientist: Introductory statistics using generalized linear models*. Sage.

Ida, T., Murakami, K. and Tanaka, M. (2014) ‘A stated preference analysis of smart meters, photovoltaic generation, and electric vehicles in Japan: Implications for penetration and GHG reduction’, *Energy Research & Social Science*. Elsevier, 2, pp. 75–89. doi: 10.1016/J.ERSS.2014.04.005.

IEA (2020) *World Energy Outlook 2020*. Available at: https://www.oecd-ilibrary.org/energy/world-energy-outlook-2020_557a761b-en.

IFC (2019) *The Dirty Footprint of the Broken Grid The Impacts of Fossil Fuel Back-up Generators in Developing Countries*. Available at: www.ifc.org.

Ikäheimo, J. *et al.* (2018) ‘Power-to-ammonia in future North European 100% renewable power and heat system’, *International Journal of Hydrogen Energy*. Elsevier, 43(36), pp. 17295–17308.

International Energy Agency (IEA) (2011) *Energy for All: Financing access for the poor (Special early excerpt of the World Energy Outlook 2011)*, *World Energy Outlook 2011*. Available at: http://www.iea.org/media/weowebsite/energydevelopment/weo2011_energy_for_all-1.pdf.

International Energy Agency (IEA) (2021) ‘Renewables 2021 - Analysis and forecast to 2026’. Available at: www.iea.org/t&c/.

International Renewable Energy Agency (IRENA) (2020) *Peer-to-peer electricity trading: Innovation Landscape Brief*. Abu Dhabi. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Peer-to-peer_trading_2020.pdf?la=en&hash=D3E25A5BBA6FAC15B9C193F64CA3C8CBF

E3F6F41.

International Renewable Energy Agency (IRENA) (2022) *Renewable Capacity Statistics 2022*. Abu Dhabi. Available at: https://www.irena.org/publications/2022/Apr/Renewable-Capacity-Statistics-2022.

Islam, T. (2014) 'Household level innovation diffusion model of photo-voltaic (PV) solar cells from stated preference data'. doi: 10.1016/J.ENPOL.2013.10.004.

Islam, T., Louviere, J. J. and Burke, P. F. (2007) 'Modeling the effects of including/excluding attributes in choice experiments on systematic and random components', *International Journal of Research in Marketing*. North-Holland, 24(4), pp. 289–300. doi: 10.1016/j.ijresmar.2007.04.002.

Iyogun, K., Lateef, S. A. and Ana, G. R. E. E. (2018) 'Lung Function of Grain Millers Exposed to Grain Dust and Diesel Exhaust in Two Food Markets in Ibadan Metropolis, Nigeria', *Safety and Health at Work*. Elsevier. doi: 10.1016/J.SHAW.2018.01.002.

Jacal, S. *et al.* (2022) 'Economic costs and environmental impacts of fossil fuel dependency in sub-Saharan Africa: A Nigerian dilemma', *Energy for Sustainable Development*. Elsevier, 70, pp. 45–53.

Jang, J., Lee, J. and Yoo, S. H. (2014) 'The public's willingness to pay for securing a reliable natural gas supply in Korea', *Energy Policy*. Elsevier, 69, pp. 3–13. doi: 10.1016/j.enpol.2014.02.035.

Janssen, E. M., Hauber, A. B. and Bridges, J. F. P. (2018) 'Conducting a Discrete-Choice Experiment Study Following Recommendations for Good Research Practices: An Application for Eliciting Patient Preferences for Diabetes Treatments', *Value in Health*, 21(1). doi: 10.1016/j.jval.2017.07.001.

Jaynes, J., Wong, W. K. and Xu, H. (2016) 'Using blocked fractional factorial designs to construct discrete choice experiments for healthcare studies', *Statistics in Medicine*, 35(15). doi: 10.1002/sim.6882.

Al Jazeera (2017) *Nigeria fuel crisis spawns thriving black market | News | Al Jazeera*, *Al Jazeera*. Available at: https://www.aljazeera.com/news/2017/12/nigeria-fuel-crisis-black-market-thrives-price-rises-171228110121810.html.

Johnson, F. R. *et al.* (2013) 'Constructing Experimental Designs for Discrete-Choice Experiments: Report of the ISPOR Conjoint Analysis Experimental Design Good Research Practices Task Force', *Value in Health*. Elsevier, 16(1), pp. 3–13. doi: 10.1016/J.JVAL.2012.08.2223.

Johnston, R. J. *et al.* (2017) 'Contemporary guidance for stated preference studies', *Journal of the Association of Environmental and Resource Economists*, 4(2), pp. 319–405. doi: 10.1086/691697.

Jugder, N. (2016) *The thematic analysis of interview data: an approach used to examine the influence of the market on curricular provision in Mongolian higher* *education institutions*. Available at: http://hpp.education.leeds.ac.uk/wp-content/uploads/sites/131/2016/02/HPP2016-3-Jugder.pdf.

Junlakarn, S., Kokchang, P. and Audomvongseree, K. (2022) 'Drivers and Challenges of Peer-to-Peer Energy Trading Development in Thailand', *Energies*. MDPI, 15(3), p. 1229.

Kakoulaki, G. *et al.* (2021) 'Green hydrogen in Europe–A regional assessment: Substituting existing production with electrolysis powered by renewables', *Energy Conversion and Management*. Elsevier, 228, p. 113649.

Kalkbrenner, B. J. (2019) 'Residential vs. community battery storage systems – Consumer preferences in Germany', *Energy Policy*. Elsevier, 129, pp. 1355–1363. doi: 10.1016/J.ENPOL.2019.03.041.

Kalkbrenner, B. J., Yonezawa, K. and Roosen, J. (2017) 'Consumer preferences for electricity tariffs: Does proximity matter?', *Energy Policy*, 107. doi: 10.1016/j.enpol.2017.04.009.

Karami, M. and Madlener, R. (2022) 'Business models for peer-to-peer energy trading in Germany based on households' beliefs and preferences', *Applied Energy*. Elsevier, 306, p. 118053. doi: 10.1016/j.apenergy.2021.118053.

Karlstrøm, H. and Ryghaug, M. (2014) 'Public attitudes towards renewable energy technologies in Norway. The role of party preferences', *Energy Policy*. Elsevier, 67, pp. 656–663. doi: 10.1016/J.ENPOL.2013.11.049.

Kenton, W. (2021) *Understanding Autarky With Real World Examples*, *Investopedia*. Available at: https://www.investopedia.com/terms/a/autarky.asp.

Kim, H.-J., Lee, H.-J. and Yoo, S.-H. (2018) 'Are South Korean people willing to pay for official development assistance for building renewable power plants in developing countries?', *Energy Policy*. Elsevier. doi: 10.1016/J.ENPOL.2018.03.054.

Kim, J., Park, S. Y. and Lee, J. (2018) 'Do people really want renewable energy? Who wants renewable energy?: Discrete choice model of reference-dependent preference in South Korea', *Energy Policy*. Elsevier, 120, pp. 761–770. doi: 10.1016/J.ENPOL.2018.04.062.

Kılıç, U. and Kekezoğlu, B. (2022) 'A review of solar photovoltaic incentives and Policy: Selected countries and Turkey', *Ain Shams Engineering Journal*. Elsevier, 13(5), p. 101669. doi: 10.1016/J.ASEJ.2021.101669.

Kløjgaard, M. E., Bech, M. and Søgaard, R. (2012) 'Designing a Stated Choice Experiment: The Value of a Qualitative Process', *Journal of Choice Modelling*. Elsevier, 5(2), pp. 1–18. doi: 10.1016/S1755-5345(13)70050-2.

Koirala, B. P. *et al.* (2018) 'Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems', *Energy Research & Social Science*. Elsevier, 38, pp. 33–

40. doi: 10.1016/J.ERSS.2018.01.009.

Kokchang, P., Junlakarn, S. and Audomvongseree, K. (2020) ‘Business model and market designs for solar prosumer on peer to peer energy trading in Thailand’. doi: 10.1088/1755-1315/463/1/012127.

Korcaj, L., Hahnel, U. J. J. and Spada, H. (2015) ‘Intentions to adopt photovoltaic systems depend on homeowners’ expected personal gains and behavior of peers’, *Renewable Energy*. Pergamon, 75, pp. 407–415. doi: 10.1016/j.renene.2014.10.007.

Krinsky, I. and Robb, A. L. (1986) ‘On Approximating the Statistical Properties of Elasticities’, *The Review of Economics and Statistics*. JSTOR, 68(4), p. 715. doi: 10.2307/1924536.

Kroes, E. P. and Sheldon, R. J. (1988) ‘“ Stated Preference Methods—An Introduction.”’, *Journal of Transport Economics and Policy*, pp. 11–25. Available at: http://www.bath.ac.uk/e-journals/jtep/pdf/Volume_XX11_No_1_11-25.pdf.

Kruijshaar, M. E. *et al.* (2009) ‘A labelled discrete choice experiment adds realism to the choices presented: Preferences for surveillance tests for Barrett esophagus’, *BMC Medical Research Methodology*. doi: 10.1186/1471-2288-9-31.

Ku, S.-J. and Yoo, S.-H. (2010) ‘Willingness to pay for renewable energy investment in Korea: A choice experiment study’, *Renewable and Sustainable Energy Reviews*. Pergamon, 14(8), pp. 2196–2201. doi: 10.1016/J.RSER.2010.03.013.

Kubli, M., Loock, M. and Wüstenhagen, R. (2018) ‘The flexible prosumer: Measuring the willingness to co-create distributed flexibility’, *Energy Policy*. Elsevier, 114, pp. 540–548. doi: 10.1016/J.ENPOL.2017.12.044.

Lagarde, M. and Blaauw, D. (2009) ‘A review of the application and contribution of discrete choice experiments to inform human resources policy interventions’, *Human Resources for Health*. BioMed Central, 7(1), p. 62. doi: 10.1186/1478-4491-7-62.

Lancaster, K. J. (1966) ‘A New Approach to Consumer Theory’, *Journal of Political Economy*, 74(2), pp. 132–157. doi: 10.1086/259131.

Lancsar, E. *et al.* (2013) ‘Best worst discrete choice experiments in health: Methods and an application’, *Social Science & Medicine*. Pergamon, 76, pp. 74–82. doi: 10.1016/J.SOCSCIMED.2012.10.007.

Lancsar, E., Fiebig, D. G. and Hole, A. R. (2017) ‘Discrete Choice Experiments: A Guide to Model Specification, Estimation and Software’, *PharmacoEconomics*, 35(7), pp. 697–716. doi: 10.1007/s40273-017-0506-4.

Lancsar, E. and Swait, J. (2014) ‘Reconceptualising the External Validity of Discrete Choice Experiments’, *PharmacoEconomics*. Springer International Publishing, 32(10), pp. 951–965. doi: 10.1007/s40273-014-0181-7.

LeCompte, M. D. and Goetz, J. P. (1982) ‘Problems of reliability and validity in ethnographic research', *Review of educational research*. Sage Publications Sage CA: Thousand Oaks, CA, 52(1), pp. 31–60.

Lee, C.-Y. and Heo, H. (2016) 'Estimating willingness to pay for renewable energy in South Korea using the contingent valuation method', *Energy Policy*. Elsevier, 94, pp. 150–156. doi: 10.1016/J.ENPOL.2016.03.051.

Lee, E. *et al.* (2020) 'From intention to action: Habits, feedback and optimizing energy consumption in South Korea', *Energy Research and Social Science*. Elsevier Ltd, 64. doi: 10.1016/j.erss.2020.101430.

Lemaire, X. (2009) 'Fee-for-service companies for rural electrification with photovoltaic systems: The case of Zambia', *Energy for Sustainable Development*. Elsevier, 13(1), pp. 18–23. doi: 10.1016/J.ESD.2009.01.001.

Lemaire, X. (2018) 'Solar home systems and solar lanterns in rural areas of the Global South: What impact?', *Wiley Interdisciplinary Reviews: Energy and Environment*. John Wiley and Sons Ltd, 7(5). doi: 10.1002/WENE.301.

Lienhoop, N. (2018) 'Acceptance of wind energy and the role of financial and procedural participation: An investigation with focus groups and choice experiments', *Energy Policy*. Elsevier, 118, pp. 97–105. doi: 10.1016/J.ENPOL.2018.03.063.

Lim, S.-Y., Kim, H.-J. and Yoo, S.-H. (2017) 'Public's willingness to pay a premium for bioethanol in Korea: A contingent valuation study', *Energy Policy*. Elsevier, 101, pp. 20–27. doi: 10.1016/J.ENPOL.2016.11.010.

Liu, H. *et al.* (2019) 'Techno-economic feasibility assessment of grid-defection', *International Journal of Electrical Power & Energy Systems*. Elsevier, 109, pp. 403–412. doi: 10.1016/J.IJEPES.2019.01.045.

Liu, Y., Wu, L. and Li, J. (2019) 'Peer-to-peer (P2P) electricity trading in distribution systems of the future'. doi: 10.1016/J.TEJ.2019.03.002.

Liu, Y., Yang, D. and Xu, H. (2017) 'Factors Influencing Consumer Willingness to Pay for Low-Carbon Products: A Simulation Study in China', *Business Strategy and the Environment*. Wiley-Blackwell, 26(7), pp. 972–984. doi: 10.1002/bse.1959.

Löbbe, S. and Hackbarth, A. (2017) 'The Transformation of the German Electricity Sector and the Emergence of New Business Models in Distributed Energy Systems', in *Innovation and Disruption at the Grid's Edge*. Elsevier, pp. 287–318. doi: 10.1016/B978-0-12-811758-3.00015-2.

Longo, A., Markandya, A. and Petrucci, M. (2008) 'The internalization of externalities in the production of electricity: Willingness to pay for the attributes of a policy for renewable energy', *Ecological Economics*. Elsevier, 67(1), pp. 140–152. doi: 10.1016/J.ECOLECON.2007.12.006.

Louviere, J. J. (2001) 'Choice experiments: an overview of concepts and issues', *The choice modelling approach to environmental valuation*. Edward Elgar, Northampton, UK, pp. 13–36.

Louviere, J. J., Pihlens, D. and Carson, R. (2011) ‘Design of Discrete Choice Experiments: A Discussion of Issues That Matter in Future Applied Research’, *Journal of Choice Modelling*. Elsevier, 4(1), pp. 1–8. doi: 10.1016/S1755-5345(13)70016-2.

Lowitzsch, J., Hoicka, C. E. and van Tulder, F. J. (2020) ‘Renewable energy communities under the 2019 European Clean Energy Package–Governance model for the energy clusters of the future?’, *Renewable and Sustainable Energy Reviews*. Elsevier, 122, p. 109489.

Ma, C. *et al.* (2015) ‘Consumers’ willingness to pay for renewable energy: A meta-regression analysis’, *Resource and Energy Economics*. North-Holland, 42, pp. 93–109. doi: 10.1016/J.RESENEECO.2015.07.003.

Mangham, L. J., Hanson, K. and McPake, B. (2009) ‘How to do (or not to do) ... Designing a discrete choice experiment for application in a low-income country’, *Health Policy and Planning*. Oxford University Press, 24(2), pp. 151–158. doi: 10.1093/heapol/czn047.

Manski, C. F. (1977) ‘The structure of random utility models’, *Theory and decision*. Springer, 8(3), pp. 229–254.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, J. B., *et al.* (2021) ‘Environmental Valuation with Discrete Choice Experiments’. Cham: Springer International Publishing (SpringerBriefs in Economics). doi: 10.1007/978-3-030-62669-3.

Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jette, ·, *et al.* (2021) *Environmental Valuation with Discrete Choice Experiments Guidance on Design, Implementation and Data Analysis*. SPRINGER BRIEFS IN ECONOMICS. Available at: https://link.springer.com/content/pdf/10.1007%2F978-3-030-62669-3.pdf.

Matyas, M. (2020) *Investigating Individual Preferences for New Mobility Services : the Case of “Mobility as a Service” Products*, *UCL (University College London)*. UCL (University College London). Available at: https://discovery.ucl.ac.uk/id/eprint/10091070/.

Maxim, P. S. (1999) *Quantitative Research Methods in the Social Sciences Oxford University Press*. New York: Oxford University Press.

Mayas, M. and Kamargianni, M. (2017) ‘Stated Preference Design for Exploring Demand for “Mobility as a Service” Plans’, *5th International Choice Modelling Conference*. Available at: https://docs.wixstatic.com/ugd/a2135d_d85b6b0955d5458a81db61bc8edc02a2.pdf.

Mbamali, I., Stanley, A. M. and Zubairu, I. K. (2012) ‘Evironmental , Health and Social Hazards of Fossil Fuel Electricity Generators : A Users ’ Assessment in Kaduna , Nigeria', *American International Journal of Contemporary Research*, 2(9), pp. 237–245. Available at: http://www.aijcrnet.com/journals/Vol_2_No_9_September_2012/28.pdf.

McFadden, D. (1974) 'Analysis of Qualitative Choice Behavior. Zarembka, P.(ed.): Frontiers in Econometrics'. Academic Press. New York, NY.

McFadden, D. and Train, K. (2000) 'Mixed MNL models for discrete response', *Journal of applied Econometrics*. Wiley Online Library, 15(5), pp. 447–470.

Meijer, E. and Rouwendal, J. (2006) 'Measuring welfare effects in models with random coefficients', *Journal of Applied Econometrics*, 21(2), pp. 227–244. doi: 10.1002/jae.841.

Menegaki, A. (2008) 'Valuation for renewable energy: A comparative review', *Renewable and Sustainable Energy Reviews*. Pergamon, 12(9), pp. 2422–2437. doi: 10.1016/J.RSER.2007.06.003.

Mengelkamp, E. *et al.* (2017) 'Designing microgrid energy markets: A case study: The Brooklyn Microgrid', *Applied Energy*. doi: https://doi.org/10.1016/j.apenergy.2017.06.054.

Mengelkamp, E. *et al.* (2018) 'A blockchain-based smart grid: towards sustainable local energy markets', *Computer Science - Research and Development*. Springer Berlin Heidelberg, 33(1–2), pp. 207–214. doi: 10.1007/s00450-017-0360-9.

Mengelkamp, E. *et al.* (2019) 'The value of local electricity - A choice experiment among German residential customers', *Energy Policy*. Elsevier, 130, pp. 294–303. doi: 10.1016/J.ENPOL.2019.04.008.

Menkiti, N. U. and Agunwamba, J. C. (2015) 'Assessment of noise pollution from electricity generators in a high-density residential area', *African Journal of Science, Technology, Innovation and Development*, 7(4), pp. 306–312. doi: 10.1080/20421338.2015.1082370.

Merriam-Webster Dictionary (2022) *Autarky Definition & Meaning - Merriam-Webster*. Available at: https://www.merriam-webster.com/dictionary/autarky.

Miles, M. B. and Huberman, A. M. (1994) *Qualitative data analysis: An expanded sourcebook*. sage.

Mishra, P. and Behera, B. (2016) 'Socio-economic and environmental implications of solar electrification: Experience of rural Odisha', *Renewable and Sustainable Energy Reviews*. Pergamon, 56, pp. 953–964. doi: 10.1016/J.RSER.2015.11.075.

Moreno, A. and Bareisaite, A. (2015) 'Scaling Up Access to Electricity: Pay-as-You-Go Plans in Off-Grid Energy Services', *Livewire*, pp. 1–8. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/21360/937860REPF0BRI0ries00000LW150340OKR.pdf?sequence=8.

Morgan, D. L. (2007) 'Paradigms Lost and Pragmatism Regained', *Journal of Mixed Methods Research*. SAGE Publications, 1(1), pp. 48–76. doi: 10.1177/2345678906292462.

Morgenstern, P. (2016) *Understanding hospital electricity use: an end-use(r) perspective*. University College London. Available at: http://discovery.ucl.ac.uk/1514500/.

Morrissey, K., Plater, A. and Dean, M. (2018) 'The cost of electric power outages in the residential sector: A willingness to pay approach', *Applied Energy*. Elsevier, 212, pp. 141–150. doi: 10.1016/J.APENERGY.2017.12.007.

Morstyn, T. *et al.* (2018) 'Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants', *Nature Energy*. Springer US, 3(2), pp. 94–101. doi: 10.1038/s41560-017-0075-y.

Morstyn, T. and McCulloch, M. D. (2020) 'Peer-to-peer energy trading', in *Analytics for the Sharing Economy: Mathematics, Engineering and Business Perspectives*. Springer International Publishing, pp. 279–300. doi: 10.1007/978-3-030-35032-1_16.

Morstyn, T., Teytelboym, A. and McCulloch, M. D. (2019a) 'Bilateral contract networks for peer-to-peer energy trading', *IEEE Transactions on Smart Grid*. doi: 10.1109/TSG.2017.2786668.

Morstyn, T., Teytelboym, A. and McCulloch, M. D. (2019b) 'Designing decentralized markets for distribution system flexibility', *IEEE Transactions on Power Systems*. doi: 10.1109/TPWRS.2018.2886244.

Moss, T. and Gleave, M. (2014) *How Can Nigeria Cut CO2 Emissions by 63%? Build More Power Plants*, *Center for Global Development*. Available at: https://www.cgdev.org/blog/how-can-nigeria-cut-co2-emissions-63-build-more-power-plants.

Mühlbacher, A. and Johnson, F. R. (2016) 'Choice Experiments to Quantify Preferences for Health and Healthcare: State of the Practice', *Applied Health Economics and Health Policy*. Springer International Publishing, 14(3), pp. 253–266. doi: 10.1007/s40258-016-0232-7.

Müller, M. O. *et al.* (2011) 'Energy autarky: A conceptual framework for sustainable regional development', *Energy Policy*. Elsevier, 39(10), pp. 5800–5810. doi: 10.1016/j.enpol.2011.04.019.

Mulugetta, Y., Ben Hagan, E. and Kammen, D. (2019) 'Energy access for sustainable development', *Environmental Research Letters*. IOP Publishing, 14(2), p. 20201. doi: 10.1088/1748-9326/aaf449.

Murphy, J. P. (1990) *Pragmatism: From Peirce to Davidson*. CO: Westview Press.

Namkung, Y. and Jang, S. (Shawn) (2017) 'Are Consumers Willing to Pay more for Green Practices at Restaurants?', *Journal of Hospitality and Tourism Research*, 41(3), pp. 329–356. doi: 10.1177/1096348014525632.

Narain, U. (World B. *et al.* (2016) *The Cost of Air Pollution*. doi: 10.1038/nature06042.

National Bureau of Statistics and World Bank (2019) *LSMS Integrated Surveys on Agriculture Nigeria General Household SurveyPanel, Wave 4*. Available at: https://microdata.worldbank.org/index.php/catalog/3557/download/47679.

Nduka, E. (2021) ‘How to get rural households out of energy poverty in Nigeria: A contingent valuation’, *Energy Policy*. Elsevier Ltd, 149, p. 112072. doi: 10.1016/j.enpol.2020.112072.

Nduka, E. (2022) ‘Reducing carbon footprint by replacing generators with solar PV systems: a contingent valuation study in Lagos, Nigeria’, *Environment and Development Economics*. Cambridge University Press, pp. 1–22.

Netherlands Enterprise Agency (2021) *Solar Report Nigeria*. Available at: https://www.rvo.nl/sites/default/files/2021/06/Solar-Report-Nigeria.pdf.

Neumann, R. and Mehlkop, G. (2020) ‘Framing electricity plan choices to enhance green energy usage: A choice experiment with panel data from Germany’, *Energy Research and Social Science*. Elsevier Ltd, 70, p. 101741. doi: 10.1016/j.erss.2020.101741.

Neves, D., Scott, I. and Silva, C. A. (2020) ‘Peer-to-peer energy trading potential: An assessment for the residential sector under different technology and tariff availabilities’, *Energy*, 205, p. 118023.

Nguyen, S. *et al.* (2018) ‘Optimizing rooftop photovoltaic distributed generation with battery storage for peer-to-peer energy trading’, *Applied Energy*. Elsevier, 228, pp. 2567–2580. doi: 10.1016/J.APENERGY.2018.07.042.

Noel, L. *et al.* (2019) ‘Willingness to pay for electric vehicles and vehicle-to-grid applications: A Nordic choice experiment’, *Energy Economics*. Elsevier B.V., 78, pp. 525–534. doi: 10.1016/j.eneco.2018.12.014.

Odutola, A. (2021) ‘World Bank: 62% of Nigerian power consumers believe sector is inefficiently managed - Nairametrics’, *Nairametrics*, 26 April. Available at: https://nairametrics.com/2021/04/25/world-bank-62-of-nigerian-power-consumers-believe-sector-is-inefficiently-managed/.

Oerlemans, L. A. G., Chan, K.-Y. and Volschenk, J. (2016) ‘Willingness to pay for green electricity: A review of the contingent valuation literature and its sources of error’, *Renewable and Sustainable Energy Reviews*. Pergamon, 66, pp. 875–885. doi: 10.1016/J.RSER.2016.08.054.

Ofgem (2018) *What is a regulatory sandbox?* Available at: https://www.ofgem.gov.uk/publications-and-updates/what-regulatory-sandbox.

Ohiare, S. M. (2014) *Financing Rural Energy Projects in Developing Countries: A*

Case Study of Nigeria. De Montfort University. Available at: http://hdl.handle.net/2086/10462.

Ohunakin, O. S. *et al.* (2014) ‘Solar energy applications and development in Nigeria: Drivers and barriers’, *Renewable and Sustainable Energy Reviews*. Elsevier, 32, pp. 294–301. doi: 10.1016/j.rser.2014.01.014.

Okwuibe, G. C. (2019) *Peer-to-peer Energy Trading of Renewable Energies in the Nigerian Energy System on a Blockchain Platform*. Technische Universität München.

Oladapo, R. A. (2017) ‘Gender bias in the selection of Estate Surveyors and Valuers in Lagos property market’, *FUTY Journal of the Environment*, 11(1), pp. 101–111.

Olanite, O. A. and Nwohu, M. N. (2022) ‘Adoption of Photovoltaic Technologies in Nigeria: A Study of Issues, Problems and Solutions’, *Proceedings of the 2022 IEEE Nigeria 4th International Conference on Disruptive Technologies for Sustainable Development, NIGERCON 2022*. Institute of Electrical and Electronics Engineers Inc. doi: 10.1109/NIGERCON54645.2022.9803109.

Olanrewaju, B. T. *et al.* (2019) ‘A panel data analysis of renewable energy consumption in Africa’, *Renewable energy*. Elsevier, 140, pp. 668–679.

Oluwunmi, A. O. *et al.* (2017) ‘Gender inequality and women discrimination in the real estate firms in Lagos State, Nigeria’, in *Proceedings of the 29th International Business Information Management Association Conference - Education Excellence and Innovation Management through Vision 2020: From Regional Development Sustainability to Global Economic Growth*, pp. 4367–4377.

Onwuegbuzie, A. J. and Johnson, R. B. (2004) ‘Mixed Methods Research: A Research Paradigm Whose Time Has Come’, *Educational Researcher*, 33(7), pp. 14–26. doi: 10.3102/0013189X033007014.

Onwuka, S. U., Ezigbo, C. M. and Eneche, P. S. U. (2017) ‘Assessment of Noise Pollution from Power Generating Sets: A Case Study of Nnewi-North L.G.A, Nigeria’, (3), pp. 1–12. doi: 10.9734/JSRR/2017/36092.

Oparaku, O. U. (2002) ‘Photovoltaic systems for distributed power supply in Nigeria’, *Renewable Energy*. Pergamon, 25(1), pp. 31–40. doi: 10.1016/S0960-1481(00)00203-2.

Oparaku, O. U. (2003) ‘Rural area power supply in Nigeria: A cost comparison of the photovoltaic, diesel/gasoline generator and grid utility options’, *Renewable Energy*. Pergamon, 28(13), pp. 2089–2098. doi: 10.1016/S0960-1481(03)00009-0.

Orcutt, M. (2017) *How Blockchain Could Give Us a Smarter Energy Grid - MIT Technology Review*, *MIT Technology Review*. Available at: https://www.technologyreview.com/s/609077/how-blockchain-could-give-us-a-smarter-energy-grid/.

Osagie, I. *et al.* (2016) ‘Hazards Assessment Analyses of Fossil-fuel Generators:

Holistic-study of Human Experiences and Perceptions in South-Southern Nigeria', *Journal of Sustainable Development Studies*, 9(2). Available at: http://infinitypress.info/index.php/jsds/article/view/1318.

Oseni, M. O. (2015) 'Assessing the consumers' willingness to adopt a prepayment metering system in Nigeria', *Energy Policy*. Elsevier, 86, pp. 154–165. doi: 10.1016/J.ENPOL.2015.06.038.

Oseni, M. O. (2016) 'Get rid of it : To what extent might improved reliability reduce self-generation in Nigeria ?', *Energy Policy*. Elsevier, 93, pp. 246–254. doi: 10.1016/j.enpol.2016.03.013.

Osiolo, H. H. (2017) 'Willingness to pay for improved energy: Evidence from Kenya', *Renewable Energy*, 112. doi: 10.1016/j.renene.2017.05.004.

Östlund, U. *et al.* (2011) 'Combining qualitative and quantitative research within mixed method research designs: A methodological review', *International Journal of Nursing Studies*. Pergamon, 48(3), pp. 369–383. doi: 10.1016/J.IJNURSTU.2010.10.005.

Otegbulu, A. C. (2011) 'A contingent valuation model for assessing electricity demand', *Journal of Financial Management of Property and Construction*. Emerald Group Publishing Limited, 16(2), pp. 126–146. doi: 10.1108/13664381111153114.

Oyekola, A. (2020) 'Decentralized Solar Photovoltaic Distributed Generation Integrated with Blockchain Technology: A Case Study in Lagos'. Auckland University of Technology. Available at: https://openrepository.aut.ac.nz/handle/10292/13224.

Oyinbo, O. *et al.* (2019) 'Farmers' preferences for high-input agriculture supported by site-specific extension services: Evidence from a choice experiment in Nigeria', *Agricultural Systems*. Elsevier, 173, pp. 12–26. doi: 10.1016/J.AGSY.2019.02.003.

Özbafli, A. (2011) *Estimating the willingness to pay for a reliable electricity supply in the Turkish Republic of Northern Cyprus*, *Thesis*. University of Birmingham. Available at: http://etheses.bham.ac.uk/3265/1/Ozbafli12PhD.pdf.

Palm, A. (2017) 'Peer effects in residential solar photovoltaics adoption—A mixed methods study of Swedish users', *Energy Research & Social Science*. Elsevier, 26, pp. 1–10. doi: 10.1016/J.ERSS.2017.01.008.

Palm, A. (2020) 'Early adopters and their motives: Differences between earlier and later adopters of residential solar photovoltaics', *Renewable and Sustainable Energy Reviews*, 133, p. 110142. doi: 10.1016/j.rser.2020.110142.

Palm, J. (2018) 'Household installation of solar panels – Motives and barriers in a 10-year perspective', *Energy Policy*. Elsevier, 113, pp. 1–8. doi: 10.1016/J.ENPOL.2017.10.047.

Parag, Y. and Sovacool, B. K. (2016) 'Electricity market design for the prosumer era', *Nature Energy*. Macmillan Publishers Limited, 1, p. 16032. Available at: http://dx.doi.org/10.1038/nenergy.2016.32.

Paravantis, J. A. *et al.* (2018) 'Social acceptance of renewable energy projects: A contingent valuation investigation in Western Greece', *Renewable Energy*. Pergamon, 123, pp. 639–651. doi: 10.1016/J.RENENE.2018.02.068.

Park, C. and Yong, T. (2017) 'Comparative review and discussion on P2P electricity trading', in *Energy Procedia*. doi: 10.1016/j.egypro.2017.09.003.

Patton, M. Q. (1990) *Qualitative evaluation and research methods, 2nd ed.*, *Qualitative evaluation and research methods, 2nd ed.* Thousand Oaks, CA, US: Sage Publications, Inc.

Pedersen, L. B. *et al.* (2011) 'Does the inclusion of a cost attribute in forced and unforced choices matter? Results from a web survey applying the discrete choice experiment', *Journal of Choice Modelling*. Elsevier Ltd, 4(3), pp. 88–109. doi: 10.1016/S1755-5345(13)70044-7.

Petrovich, B., Hille, S. L. and Wüstenhagen, R. (2019) 'Beauty and the budget: A segmentation of residential solar adopters', *Ecological Economics*, 164, p. 106353. doi: 10.1016/j.ecolecon.2019.106353.

Polis, H. J., Dreyer, S. J. and Jenkins, L. D. (2017) 'Public Willingness to Pay and Policy Preferences for Tidal Energy Research and Development: A Study of Households in Washington State', *Ecological Economics*. Elsevier, 136, pp. 213–225. doi: 10.1016/J.ECOLECON.2017.01.024.

Potoglou, D. *et al.* (2020) 'Consumer intentions for alternative fuelled and autonomous vehicles: A segmentation analysis across six countries', *Transportation Research Part D: Transport and Environment*. Elsevier Ltd, 79, p. 102243. doi: 10.1016/j.trd.2020.102243.

Puig, D. *et al.* (2021) 'An action agenda for Africa's electricity sector', *Science*. American Association for the Advancement of Science, pp. 616–619. doi: 10.1126/science.abh1975.

Quaife, M. *et al.* (2016) 'Preferences for ARV-based HIV prevention methods among men and women, adolescent girls and female sex workers in Gauteng Province, South Africa: a protocol for a discrete choice experiment', *BMJ Open*, 6, p. 10682. doi: 10.1136/bmjopen-2015.

Quaife, M. *et al.* (2018) 'How well do discrete choice experiments predict health choices? A systematic review and meta-analysis of external validity', *The European Journal of Health Economics*. Springer Berlin Heidelberg, 19(8), pp. 1053–1066. doi: 10.1007/s10198-018-0954-6.

Quaife, M. (2018) *Using stated preferences to estimate the impact and cost-effectiveness of new HIV prevention products in South Africa*. London School of Hygiene & Tropical Medicine. Available at: http://researchonline.lshtm.ac.uk/4646708/.

R Development Core Team (2019) 'R: The R Project for Statistical Computing'. The R Foundation for Statistical Computing. Available at: https://www.r-project.org/.

Radwan, I. and Pellegrini, G. (2010) *Knowledge, Productivity, and Innovation in Nigeria Creating a New Economy*, *Directions in Development*. Washington, DC: World Bank. Available at: http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/Knowledge_productivity_innovation_Nigeria.pdf.

Rai, V., Reeves, D. and Margolis, R. (2016) 'Overcoming barriers and uncertainties in the adoption of residential solar PV'. doi: 10.1016/J.RENENE.2015.11.080.

Rai, V. and Sigrin, B. (2013) 'Diffusion of Environmentally-Friendly Energy Technologies: Buy vs. Lease Differences in Residential PV Markets'. doi: 10.1088/1748-9326/8/1/014022.

Rakotonarivo, O. S., Schaafsma, M. and Hockley, N. (2016) *A systematic review of the reliability and validity of discrete choice experiments in valuing non-market environmental goods*, *Journal of Environmental Management*. Academic Press. Available at: https://www.sciencedirect.com/science/article/pii/S0301479716305709.

Ramachandran, V. *et al.* (2019) *The New Economy of Africa: Opportunities for Nigeria's Emerging Technology Sector*. Washington.

Reuter, E. and Loock, M. (2017) 'Empowering Local Electricity Markets : A survey study from Switzerland, Norway, Spain and Germany'. Available at: https://www.semanticscholar.org/paper/005c1bffd028c0ea7a01a0dd88490179f7f26a62.

Revelt, D. and Train, K. (1998) 'Mixed logit with repeated choices: households' choices of appliance efficiency level', *Review of economics and statistics*. MIT Press, 80(4), pp. 647–657.

Van Rijnsoever, F. J., Van Mossel, A. and Broecks, K. P. F. (2015) 'Public acceptance of energy technologies: The effects of labeling, time, and heterogeneity in a discrete choice experiment', *Renewable and Sustainable Energy Reviews*. Elsevier, 45, pp. 817–829. doi: 10.1016/j.rser.2015.02.040.

Robson, C. (2011) *Real world research: a resource for users of social research methods in applied settings*. 3rd edn. Wiley.

Roche, M. ;, Ude, N. ; and Donald-Ofoegbu, I. (2017) 'True Cost of Electricity: Comparison of Costs of Electricity Generation in Nigeria', *Nigerian Economic Summit Group and Heinrich Böll Stiftung Nigeria*, (June), pp. 1–34. Available at: https://ng.boell.org/sites/default/files/true_cost_of_power_technical_report_final.pdf.

Roe, B. *et al.* (2001) 'US consumers' willingness to pay for green electricity', *Energy Policy*, 29(11), pp. 917–925. doi: 10.1016/S0301-4215(01)00006-4.

Rogers, J. C. *et al.* (2008) 'Public perceptions of opportunities for community-based renewable energy projects', *Energy Policy*. Elsevier, 36(11), pp. 4217–4226. doi: 10.1016/J.ENPOL.2008.07.028.

Rommel, J., Sagebiel, J. and Müller, J. R. (2016) 'Quality uncertainty and the market for renewable energy: Evidence from German consumers', *Renewable Energy*. Elsevier Ltd, 94, pp. 106–113. doi: 10.1016/j.renene.2016.03.049.

Rose, J. M. and Bliemer, M. C. J. (2009) 'Constructing Efficient Stated Choice Experimental Designs', *Transport Reviews*. Routledge, 29(5), pp. 587–617. doi: 10.1080/01441640902827623.

Rose, J. M. and Bliemer, M. C. J. (2013) 'Sample size requirements for stated choice experiments', *Transportation*. Springer US, 40(5), pp. 1021–1041. doi: 10.1007/s11116-013-9451-z.

Rossman, G. B. and Wilson, B. L. (1985) 'Numbers and Words', *Evaluation Review*. Sage PublicationsSage CA: Thousand Oaks, CA, 9(5), pp. 627–643. doi: 10.1177/0193841X8500900505.

Rural Electrification Agency (REA) (2017) *Nigeria Minigrid Investment Brief*. Available at: https://rmi.org/wp-content/uploads/2017/12/Nigeria_Minigrid_Investment_Brief_REA_RMI.pdf.

Sabadini, F. and Madlener, R. (2021) 'The Economic Potential of Grid Defection of Energy Prosumer Households in Germany', *Advances in Applied Energy*. Elsevier, p. 100075. doi: 10.1016/J.ADAPEN.2021.100075.

Sagebiel, J. (2017) *Preference heterogeneity in energy discrete choice experiments: A review on methods for model selection*, *Renewable and Sustainable Energy Reviews*. Pergamon. doi: 10.1016/j.rser.2016.11.138.

Sagebiel, J., Müller, J. R. and Rommel, J. (2014) 'Are consumers willing to pay more for electricity from cooperatives? Results from an online Choice Experiment in Germany', *Energy Research & Social Science*. Elsevier, 2, pp. 90–101. doi: 10.1016/J.ERSS.2014.04.003.

Sagebiel, J. and Rommel, K. (2014) 'Preferences for electricity supply attributes in emerging megacities — Policy implications from a discrete choice experiment of private households in Hyderabad, India', *Energy for Sustainable Development*. Elsevier, 21, pp. 89–99. doi: 10.1016/J.ESD.2014.06.002.

Salami, M. A., Adeoye, P. O. and Adegboye, V. (2010) 'Bronchogenic carcinoma: Clinicopathologic pattern in Nigerians.', *Journal of Clinical Oncology*. American Society of Clinical Oncology, 28(15_suppl), pp. e12065–e12065. doi: 10.1200/jco.2010.28.15_suppl.e12065.

Sardianou, E. and Genoudi, P. (2013) 'Which factors affect the willingness of consumers to adopt renewable energies?', *Renewable Energy*. Pergamon, 57, pp. 1–4. doi: 10.1016/J.RENENE.2013.01.031.

Sarrias, M. and Daziano, R. (2017) ‘ Multinomial Logit Models with Continuous and Discrete Individual Heterogeneity in R : The gmnl Package ’, *Journal of Statistical Software*, 79(2). doi: 10.18637/jss.v079.i02.

Scarpa, R. and Willis, K. (2010) ‘Willingness-to-pay for renewable energy: Primary and discretionary choice of British households’ for micro-generation technologies’, *Energy Economics*. North-Holland, 32(1), pp. 129–136. doi: 10.1016/J.ENECO.2009.06.004.

Schaafsma, M. *et al.* (2014) ‘Temporal stability of preferences and willingness to pay for natural areas in choice experiments: A test–retest’, *Resource and Energy Economics*. North-Holland, 38, pp. 243–260. doi: 10.1016/J.RESENEECO.2014.09.001.

Schelly, C. (2014) ‘Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters’, *Energy Research & Social Science*, 2, pp. 183–191. doi: 10.1016/j.erss.2014.01.001.

Schmidt, J. *et al.* (2012) ‘Regional energy autarky: Potentials, costs and consequences for an Austrian region’, *Energy Policy*. Elsevier, 47, pp. 211–221. doi: 10.1016/J.ENPOL.2012.04.059.

Schneiders, A. (2021) ‘Regulatory sandboxes in the energy sector: are they key to the transition to a net zero future?’, in *https://www. biee. org/resources/regulatory-sandboxes-in-the-energy-sector-are-they-key-to-the-transition-to-a-net-zero-future/*. British Institute of Energy Economics: BIEE.

Schneiders, A., Fell, M. J. and Nolden, C. (2022) ‘Peer-to-peer electricity trading and the sharing economy: social, markets and regulatory perspectives’, *https://doi.org/10.1080/15567249.2022.2050849*. Taylor & Francis. doi: 10.1080/15567249.2022.2050849.

Selander, J. *et al.* (2016) ‘Maternal Occupational Exposure to Noise during Pregnancy and Hearing Dysfunction in Children: A Nationwide Prospective Cohort Study in Sweden’, *Environmental Health Perspectives*, 124(6), pp. 855–860. doi: 10.1289/ehp.1509874.

Sever, I., Verbič, M. and Klarić Sever, E. (2018) ‘Cost attribute in health care DCEs: Just adding another attribute or a trigger of change in the stated preferences?’, *Journal of Choice Modelling*, 1 September. doi: 10.1016/j.jocm.2018.03.005.

Shen, J. and Saijo, T. (2009) ‘Does an energy efficiency label alter consumers’ purchasing decisions? A latent class approach based on a stated choice experiment in Shanghai’, *Journal of Environmental Management*. Elsevier Ltd, 90(11), pp. 3561–3573. doi: 10.1016/j.jenvman.2009.06.010.

Sillano, M. and de Dios Ortúzar, J. (2005) ‘Willingness-to-pay estimation with mixed logit models: some new evidence’, *Environment and Planning A*. SAGE Publications Sage UK: London, England, 37(3), pp. 525–550.

Silverman, D. T. *et al.* (2012) ‘The Diesel Exhaust in Miners Study: A Nested Case-Control Study of Lung Cancer and Diesel Exhaust’, *JNCI Journal of the National Cancer Institute*. Oxford University Press, 104(11), pp. 855–868. doi: 10.1093/jnci/djs034.

Simpson, G (2017) *Analysing social acceptance of renewable energy policy in Australia: community, industry and government perceptions of residential solar energy*. University of Western Australia. Available at: https://www.semanticscholar.org/paper/7c6ca54593819a1123643b2055a129d9fab561d9.

Simpson, Genevieve (2017) ‘Looking beyond incentives: the role of champions in the social acceptance of residential solar energy in regional Australian communities’, *https://doi.org/10.1080/13549839.2017.1391187*. Routledge, 23(2), pp. 127–143. doi: 10.1080/13549839.2017.1391187.

Simpson, G. and Clifton, J. (2017) ‘Testing Diffusion of Innovations Theory with data: Financial incentives, early adopters, and distributed solar energy in Australia’, *Energy Research & Social Science*, 29, pp. 12–22. doi: 10.1016/j.erss.2017.04.005.

Singh, A. *et al.* (2017) ‘Towards an ethnography of electrification in rural India: Social relations and values in household energy exchanges’, *Energy Research & Social Science*. Elsevier, 30, pp. 103–115. doi: 10.1016/J.ERSS.2017.06.031.

Siyaranamual, M. *et al.* (2020) ‘Consumers’ willingness to pay for electricity service attributes: A discrete choice experiment in urban Indonesia’, *Energy Reports*. Elsevier Ltd, 6, pp. 562–571. doi: 10.1016/j.egyr.2020.02.018.

Sokona, Y., Mulugetta, Y. and Gujba, H. (2012) ‘Widening energy access in Africa: Towards energy transition’, *Energy Policy*. Elsevier, 47(SUPPL.1), pp. 3–10. Available at: https://www.sciencedirect.com/science/article/pii/S0301421512002455.

Somefun, O. A. (2015) *The Erratic Electric Power Supply in Nigeria: Causes and Remedy*. Akure. doi: 10.13140/RG.2.1.4755.8008.

Sorin, E., Bobo, L. and Pinson, P. (2019) ‘Consensus-Based Approach to Peer-to-Peer Electricity Markets With Product Differentiation’. doi: 10.1109/TPWRS.2018.2872880.

Soto, E. A. *et al.* (2020) ‘Peer-to-peer energy trading: A review of the literature’. doi: 10.1016/j.apenergy.2020.116268.

Sousa, T. *et al.* (2019) ‘Peer-to-peer and community-based markets: A comprehensive review’, *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, pp. 367–378. doi: 10.1016/j.rser.2019.01.036.

Sovacool, B. K. (2014) ‘What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda’, *Energy Research & Social Science*, 1(Supplement C), pp. 1–29. doi:

https://doi.org/10.1016/j.erss.2014.02.003.

Soyemi, A. O. *et al.* (2021) ‘The Challenges of Estimated Billing on Electricity Consumers in Nigeria: A Review’, in *IOP Conference Series: Earth and Environmental Science*. IOP Publishing, p. 12025.

Stata Press (2019) *Stata Statistical Software: Release 16*, *StataCorp LLC*.

Stigka, E. K., Paravantis, J. A. and Mihalakakou, G. K. (2014) ‘Social acceptance of renewable energy sources: A review of contingent valuation applications’, *Renewable and Sustainable Energy Reviews*. Pergamon, 32, pp. 100–106. doi: 10.1016/J.RSER.2013.12.026.

Su, W. *et al.* (2018) ‘Valuating renewable microgeneration technologies in Lithuanian households: A study on willingness to pay’, *Journal of Cleaner Production*. Elsevier, 191, pp. 318–329. doi: 10.1016/J.JCLEPRO.2018.04.199.

Sundt, S. and Rehdanz, K. (2015a) ‘Consumers’ willingness to pay for green electricity: A meta-analysis of the literature’, *Energy Economics*. North-Holland, 51, pp. 1–8. doi: 10.1016/J.ENECO.2015.06.005.

Sundt, S. and Rehdanz, K. (2015b) ‘Consumers’ willingness to pay for green electricity: A meta-analysis of the literature’, *Energy Economics*. North-Holland, 51, pp. 1–8. doi: 10.1016/J.ENECO.2015.06.005.

Sundt, S. and Rehdanz, K. (2015c) ‘Consumers’ willingness to pay for green electricity: A meta-analysis of the literature’, *Energy Economics*, 51, pp. 1–8. doi: 10.1016/j.eneco.2015.06.005.

Sundt, S. and Rehdanz, K. (2015d) ‘Consumers’ willingness to pay for green electricity: A meta-analysis of the literature’, *Energy Economics*. Elsevier, 51, pp. 1–8. doi: 10.1016/j.eneco.2015.06.005.

Syed, M. M., Morrison, G. M. and Darbyshire, J. (2020) ‘Shared Solar and Battery Storage Configuration Effectiveness for Reducing the Grid Reliance of Apartment Complexes’, *Energies 2020, Vol. 13, Page 4820*. Multidisciplinary Digital Publishing Institute, 13(18), p. 4820. doi: 10.3390/EN13184820.

Szabo, S. *et al.* (2011) ‘Energy solutions in rural Africa: mapping electrification costs of distributed solar and diesel generation versus grid extension’, *Environmental Research Letters*. IOP Publishing, 6(3), p. 34002. doi: http://dx.doi.org/10.1088/1748-9326/6/3/034002.

Tashakkori, A. and Teddlie, C. (2010) ‘SAGE Handbook of Mixed Methods in Social & Behavioral Research’. Thousand Oaks, California. doi: 10.4135/9781506335193.

Terris-Prestholt, F., Quaife, M. and Vickerman, P. (2016) ‘Parameterising User Uptake in Economic Evaluations: The role of discrete choice experiments’, *Health Economics*, 25, pp. 116–123. doi: 10.1002/hec.3297.

The Economist (2017) ‘Renewable energy - A world turned upside down’, 25 February. Available at: https://www.economist.com/news/briefing/21717365-wind-and-solar-energy-are-disrupting-century-old-model-providing-electricity-what-will.

The McKinsey Global Institute (2014) *Nigeria’s renewal: Delivering inclusive growth in Africa’s largest economy*. Available at: https://www.mckinsey.com/~/media/McKinsey/Featured Insights/Middle East and Africa/Nigerias renewal Delivering inclusive growth/MGI_Nigerias_renewal_Full_report.pdf.

The Nigerian Tribune (2017) ‘Petrol sells for N300 per litre in black market’, *The Nigerian Tribune*, 23 December. Available at: http://www.tribuneonlineng.com/petrol-sells-n300-per-litre-black-market/.

Thompson, O. A. (2021) ‘Analysis of factors influencing households’ preference level for solar energy in urban areas of Southwest Nigeria’, *670216917*.

Timmermans, H., Van der Heuden, R. and Westerveld, H. (1982) ‘The identification of factors influencing destination choice: An application of the repertory grid methodology’, *Transportation*. Springer, 11(2), pp. 189–203.

Tinch, R. *et al.* (2019) ‘Economic valuation of ecosystem goods and services: a review for decision makers’, *https://doi.org/10.1080/21606544.2019.1623083*. Routledge, 8(4), pp. 359–378. doi: 10.1080/21606544.2019.1623083.

Trading Economics (2020) *Nigeria Living Wage Individual | 2015-2018 Data*. Available at: https://tradingeconomics.com/nigeria/living-wage-individual.

Train, K. E. (2003) *Discrete choice methods with simulation*, *Discrete Choice Methods with Simulation*. Cambridge University Press. doi: 10.1017/CBO9780511753930.

Tsantopoulos, G., Arabatzis, G. and Tampakis, S. (2014) ‘Public attitudes towards photovoltaic developments: Case study from Greece’, *Energy Policy*. Elsevier, 71, pp. 94–106. doi: 10.1016/J.ENPOL.2014.03.025.

Tu, G., Abildtrup, J. and Garcia, S. (2016) ‘Preferences for urban green spaces and peri-urban forests: An analysis of stated residential choices’, *Landscape and Urban Planning*. Elsevier, 148, pp. 120–131. doi: 10.1016/J.LANDURBPLAN.2015.12.013.

Tushar, W. *et al.* (2018) ‘Transforming Energy Networks via Peer-to-Peer Energy Trading: The Potential of Game-Theoretic Approaches’. doi: 10.1109/MSP.2018.2818327.

Tushar, W. *et al.* (2019) ‘A motivational game-theoretic approach for peer-to-peer energy trading in the smart grid’, *Applied Energy*. Elsevier, 243, pp. 10–20. doi: 10.1016/J.APENERGY.2019.03.111.

Tushar, W., Saha, T. K., Yuen, C., Morstyn, T., *et al.* (2020) ‘Grid Influenced Peer-to-Peer Energy Trading’. doi: 10.1109/TSG.2019.2937981.

Tushar, W., Yuen, C., *et al.* (2020) ‘Peer-to-Peer Energy Systems for Connected Communities: A Review of Recent Advances and Emerging Challenges’. doi: 10.1016/j.apenergy.2020.116131.

Tushar, W., Saha, T. K., Yuen, C., Smith, D., *et al.* (2020) ‘Peer-to-Peer Trading in Electricity Networks: An Overview’. doi: 10.1109/TSG.2020.2969657.

Twerefou, D. K. (2014) ‘Willingness to Pay for Improved Electricity Supply in Ghana’, *Modern Economy*, 5(May), pp. 489–498. Available at: https://pdfs.semanticscholar.org/10d4/c7d40417dd0fad4df8d4700742f0a956d509.pdf.

Ugulu, A. I. (2016) *The determinants of decentralised photovoltaic (PV) adoption in urban Nigeria and a verified model for rapid diffusion*. Heriot-Watt University.

Ugulu, A. I. and Aigbayboa, C. (2019) ‘Motives for solar photovoltaic (PV) adoption in urban Nigeria’, in *IOP Conference Series: Earth and Environmental Science* . doi: 10.1088/1755-1315/385/1/012012.

Ulsrud, K. *et al.* (2015) ‘Village-level solar power in Africa: accelerating access to electricity services through a socio-technical design in Kenya’, *Energy Research & Social Science*. Elsevier, 5, pp. 34–44. doi: https://doi.org/10.1016/j.erss.2014.12.009.

Umaru, I. G. (2016) ‘Households’ willingness to pay electricity in Northern Nigeria’, in *WEENTECH Proceedings in Energy. International Conference on Energy, Environment and Economics*.

UNFCCC (2020) *ME SOLshare: Peer-to-Peer Smart Village Grids | Bangladesh*, *United Nations Framework Convention on Climate Change*. Available at: https://cop23.unfccc.int/climate-action/momentum-for-change/ict-solutions/solshare.

Vanguard Newspaper (2013) ‘Portable generators: Standby power or standby death? - Vanguard News’, *Vanguard Newspaper*, 9 October. Available at: https://www.vanguardngr.com/2013/10/portable-generators-standby-power-standby-death/.

Varian, H. R. (1992) *Microeconomic analysis*. 3rd edn. W.W. Norton and Company Inc.

Vass, C. M. (2015) *Using discrete choice experiments to value benefits and risks in primary care*. University of Manchester. Available at: https://www.research.manchester.ac.uk/portal/files/54579019/FULL_TEXT.PDF.

Vass, C., Rigby, D. and Payne, K. (2017) ‘The Role of Qualitative Research Methods in Discrete Choice Experiments: A Systematic Review and Survey of Authors’, *Medical Decision Making*. SAGE PublicationsSage CA: Los Angeles, CA, 37(3), pp. 298–313. doi: 10.1177/0272989X16683934.

Vasseur, V. and Kemp, R. (2015) ‘The adoption of PV in the Netherlands: A statistical analysis of adoption factors’, *Renewable and Sustainable Energy Reviews*, 41, pp.

483–494. doi: 10.1016/j.rser.2014.08.020.

De Vaus, D. (2002) *Analyzing social science data: 50 key problems in data analysis*. Sage.

Veblen, T. (2007) *Theory of the Leisure Class (Oxford World's Classics)*. Transaction Publishers.

Vecchiato, D. and Tempesta, T. (2015) 'Public preferences for electricity contracts including renewable energy: A marketing analysis with choice experiments', *Energy*, 88, pp. 168–179. doi: 10.1016/j.energy.2015.04.036.

Wahab, B. and Adetunji, O. (2015) 'Conflict Resolution Strategies On Community-Driven Projects In Private And Public Housing Estates In Lagos State, Nigeria.', *African Journal For The Psychological Study Of Social Issues*, 18(2). Available at: http://ir.library.ui.edu.ng/bitstream/123456789/1273/1/%2830%29ui_art_wahab_conflict_2015.pdf.

Wahab, B. and Falola, O. (2016) 'Environmental Hazards The consequences and policy implications of urban encroachment into flood-risk areas: the case of Ibadan'. doi: 10.1080/17477891.2016.1211505.

Walliman, N. (2006) *Social research methods*. Sage.

Wang, N. *et al.* (2020) 'Modeling the decentralized energy investment and operation in the prosumer era: a systematic review'. doi: 10.1109/ISGT-Europe47291.2020.9248838.

Ward, D. O. *et al.* (2011) 'Consumer willingness to pay for appliances produced by Green Power Partners', *Energy Economics*. North-Holland, 33(6), pp. 1095–1102. doi: 10.1016/J.ENECO.2011.02.003.

Watson, N. E. *et al.* (2020) 'Two energy suppliers are better than one: Survey experiments on consumer engagement with local energy in GB', *Energy Policy*. Elsevier, 147, p. 111891. doi: 10.1016/j.enpol.2020.111891.

Wijayatunga, P. D. C. and Attalage, R. A. (2005) 'Socio-economic impact of solar home systems in rural Sri Lanka: a case-study', *Energy for Sustainable Development*. Elsevier, 9(2), pp. 5–9. doi: 10.1016/S0973-0826(08)60487-1.

Wilkinson, S. *et al.* (2020) 'Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia', *Energy Research & Social Science*. Elsevier, 66, p. 101500. doi: 10.1016/J.ERSS.2020.101500.

Wittink, L. T. (2011a) 'Choice modelling: An overview of theory and development in individual choice behaviour modelling', *BMI Paper*, (August), p. 39. Available at: https://www.few.vu.nl/nl/Images/werkstuk-wittink_tcm243-237206.pdf.

Wittink, L. T. (2011b) 'Choice modelling: An overview of theory and development in individual choice behaviour modelling', *BMI Paper*, (August), p. 39. Available at: https://beta.vu.nl/nl/Images/werkstuk-wittink%7B_%7Dtcm235-237206.pdf.

Wittink, L. T. (2011c) *Choice models*, *Axiomatic choice models and duality*. doi: 10.1007/978-94-011-9831-8_3.

Wolske, K. S., Stern, P. C. and Dietz, T. (2017) 'Explaining interest in adopting residential solar photovoltaic systems in the United States: Toward an integration of behavioral theories'. doi: 10.1016/J.ERSS.2016.12.023.

World Bank (2014) *Nigeria - Ibadan Urban Flood Management Project*. Washington, DC. Available at: http://documents.worldbank.org/curated/en/536881468144274402/Nigeria-Ibadan-Urban-Flood-Management-Project.

World Bank (2016) 'From Oil to Cities: Nigeria's Next Transformation', *Directions in Development*. Washington, DC. doi: 10.1596/ 978-1-4648-0792-3.

World Bank (2018) *Nigeria - Multi-Tier Framework for Measuring Energy Access 2018*. Available at: https://microdata.worldbank.org/index.php/catalog/3865/related-materials.

World Bank (2020a) *Nigeria - Power Sector Recovery Operation (English)*. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/991581593223433078/nigeria-power-sector-recovery-operation.

World Bank (2020b) *Population Data*, *World Development Indicators (WDI)*. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL.

World Bank (2021a) *Official exchange rate (LCU per US$, period average) - Nigeria | Data*, *World Bank Databank*. Available at: https://data.worldbank.org/indicator/PA.NUS.FCRF?locations=NG.

World Bank (2021b) *TRACKING SDG7 A joint report of the custodian agencies*. Available at: www.worldbank.org.

World Bank (2022) *RISE 2022 Regulatory Indicators for Sustainable Energy Building Resilience*. Available at: https://rise.esmap.org/data/files/reports/2022/RISE 2022 Report Building Resilience.pdf.

World Health Organization (WHO) (2012) *IARC: Diesel Engine Exhaust Carcinogenic*. Lyon. doi: 10.1093/jnci/djs034.

Xie, B.-C. and Zhao, W. (2018) 'Willingness to pay for green electricity in Tianjin, China: Based on the contingent valuation method', *Energy Policy*. Elsevier, 114, pp. 98–107. doi: 10.1016/J.ENPOL.2017.11.067.

Yamamoto, Y. (2015) 'Opinion leadership and willingness to pay for residential photovoltaic systems', *Energy Policy*. Elsevier, 83, pp. 185–192. doi:

10.1016/J.ENPOL.2015.04.014.

Yang, Z. *et al.* (2018) 'How Cognitive Bias and Information Disclosure affect the Willingness of Urban Residents to Pay for Green Power?', *Journal of Cleaner Production*. Elsevier. doi: 10.1016/J.JCLEPRO.2018.03.222.

Yesufu, L. ., Ana, G. R. E. . and Umar, O. . (2013) 'Knowledge and Perception of Noise Induced Health Hazards Associated with Generator Use in Selected Commercial Areas in Ibadan, Nigeria', *International Journal of Collaborative Research on Internal Medicine & Public Health*, 5(9).

Yin, R. K. (2008) *Case study research: design and methods*. 4th edn. Los Angeles; London: Sage Publications.

Yoo, H. Il (2019) 'lclogit2: An Enhanced Module to Estimate Latent Class Conditional Logit Models', *SSRN Electronic Journal*, pp. 1–20. doi: 10.2139/ssrn.3484429.

Zalejska-Jonsson, A. (2014) 'Stated WTP and rational WTP: Willingness to pay for green apartments in Sweden', *Sustainable Cities and Society*. Elsevier B.V., 13, pp. 46–56. doi: 10.1016/j.scs.2014.04.007.

Zha, D. *et al.* (2020) 'Appliance energy labels and consumer heterogeneity: A latent class approach based on a discrete choice experiment in China', *Energy Economics*. Elsevier BV, 90, p. 104839. doi: 10.1016/j.eneco.2020.104839.

Zhang, C. *et al.* (2017) 'Review of Existing Peer-to-Peer Energy Trading Projects', in *Energy Procedia*. Elsevier Ltd, pp. 2563–2568. doi: 10.1016/j.egypro.2017.03.737.

Zhang, C. *et al.* (2018) 'Peer-to-Peer energy trading in a Microgrid'. doi: 10.1016/J.APENERGY.2018.03.010.

Zhang, L. *et al.* (2016) 'The role of public information in increasing homebuyers' willingness-to-pay for green housing: Evidence from Beijing', *Ecological Economics*. Elsevier, 129, pp. 40–49. doi: 10.1016/J.ECOLECON.2016.05.010.

Zhang, L. and Wu, Y. (2012) 'Market segmentation and willingness to pay for green electricity among urban residents in China: The case of Jiangsu Province', *Energy Policy*. Elsevier, 51, pp. 514–523. doi: 10.1016/J.ENPOL.2012.08.053.

Zhou, Y. *et al.* (2020) 'State-of-the-Art Analysis and Perspectives for Peer-to-Peer Energy Trading'. doi: 10.1016/j.eng.2020.06.002.

Zorić, J. and Hrovatin, N. (2012) 'Household willingness to pay for green electricity in Slovenia', *Energy Policy*. Elsevier, 47, pp. 180–187. doi: 10.1016/J.ENPOL.2012.04.055.

APPENDIX

Appendix A1: Multinomial Logit Model (MNL)

Further analysis in this appendix contains the Multinomial Logit Model (MNL), also known as the Conditional Logit (CL) model, which is very common in DCE studies (Scarpa and Willis, 2010; Alem *et al.*, 2016; Sagebiel, 2017; Sarrias and Daziano, 2017). The MNL model is used to analyse the choice of a home based on its attributes and to check the effects that these attributes have on systematic/deterministic utility. One of the shortcomings of the MNL model is the IIA assumption which restricts the ability of the model to capture unobserved preference heterogeneity. This IIA restriction of the MNL specifies that the odds of the probability of choosing one class (set of alternatives) over another are independent of the wider set of alternatives in the choice set. In addition to the IIA assumption of the MNL model, it also assumes homogeneity in preferences among all respondents; that is, utility functions are the same for all respondents, which is quite unrealistic in practice because individuals have different preferences. However, as discussed earlier, the estimation would commence with the simple MNL before moving to other models that address these shortcomings. This is particularly important as subsequent models rely on the choice probability in the MNL but relax the IIA assumption.

Based on the operationalisation of the Random Utility Model (RUT) by Ben-Akiva and Lerman (1985), who provide a theoretical background for discrete choice models; then;

$$U_{in} > U_{jn} \forall j \neq i \qquad \dots (3)$$

- Where U_{in} is the highest utility of the chosen alternative and U_{jn} are the other alternatives in the choices set C_n that the individual n can choose from.
- As stated earlier, the utility of the chosen alternative has both an explainable systematic component and an unexplainable random part. This is expressed in equation form below

$$U_{in} = V_{in} + \varepsilon_{in} \qquad \dots (4)$$

- Where U_{in} is the unobserved utility that an individual n derives from an alternative i
- V_{in} is the systematic, explainable component of the utility from alternative *i,*
- ε_{in} is the random component of the utility from alternative *i*.

Due to this random component, the probability that an individual will choose a certain alternative can be calculated; however, the exact choice cannot be calculated.

The systematic component can then be modelled as the sum of part-worth utilities that depend on the various attributes and their respective levels, and this is expressed in equation 5 below. This equation shows that the systematic utility of an alternative V_{in} sums part-worth utilities.

$$V_{in} = \beta_0 + \beta_1 x_{in1} + \beta_2 x_{in2} + \cdots + \beta_k x_{ink} = \sum_k \beta_k x_{ink} \qquad \ldots (5)$$

- Where x_{ink} is the level value of an attribute represented by parameter k for alternative i that is available in the choice set of respondents n
- β_k represents the parameter that shows the contribution of parameter k on the utility of the alternative. An example of this attribute can be having a specific form of backup electricity, such as a PV system or a generator.

Based on the attributes in this study, the systematic component can be characterised as

$$V_{in} = \beta_0 + \beta_1 Backup_{in1} + \beta_2 Pollution_{in2} + \beta_3 Energytrading_{in3} + \beta_4 Houseprice_{in4} + \beta_5 Backupprice_{in5} \qquad \ldots (6)$$

A system of equations, as shown below, allows the estimation of β_k, and these estimates can be used to predict the probability P that alternative i will be chosen from choice set j. This probability is calculated as the exponential value of the systematic component of the alternative i divided by the sum of the exponential value of the systematic utility (V_{in}) for all the alternatives.

$$P(i|j) = \frac{e^{\beta_k x_{ink}}}{\sum_{i,j} e^{\beta_k x_{jnk}} + e^{\beta_k x_{ink}}} = \frac{e^{V_{in}}}{\sum_{i,j} e^{V_{jn}} + e^{V_{in}}}, \forall j \neq i \qquad \ldots (7)$$

The unknown parameters are estimated using the maximum likelihood technique. For a given sample of *N* independent observations, the log-likelihood function is written as:

$$\ln L = \sum_{n=1}^{N} \sum_{i \in S} d_{in} \ln P_n(i) , \qquad \ldots (8)$$

- Where d_{in} is an indicator variable equal to 1 if the individual n selects alternative I and 0 otherwise.

By maximising the log-likelihood function, parameter estimates are obtained (Wittink, 2011).

The coefficient interpretation for alternative i is that in comparison to the base alternative, an increase in the independent variable makes the selection of alternative i more or less likely. The marginal effect of an increase of a regressor on the probability of selecting an alternative.

The MNL model is typically estimated with alternative invariant and alternative variant regressors such that the probability that an observation i will choose alternative j is

$$p_{ij} = p(y_i = j) = \frac{exp\left(\boldsymbol{x}_{ij}'\beta + \boldsymbol{w}_i'\gamma_j\right)}{\sum_{k=1}^{m} \exp\left(\boldsymbol{x}_{ijk}'\beta + \boldsymbol{w}_i'\gamma_k\right)} \qquad \ldots (9)$$

- Where $\boldsymbol{x}_{ij}'$ are alternative specific regressors and $\boldsymbol{w}_i'$ are individual-specific regressors

The alternative-specific constants capture the mean of the error term for the utility of an alternative in a choice model. In other words, they measure the average effect of all the factors that are not included in the model on utility. The alternative invariant or alternative specific regressors vary over the individual and the alternative. For example, prices for the products vary for each product, and individuals may also pay different prices. It is used in the conditional and mixed logit models. A good pseudo-Rsquare for MNL ranges between 0.2 and 0.4.[45] The magnitude of coefficients from a logit regression has been reported to possess little direct interpretive value (Hensher, Rose and Greene, 2005). However, the coefficient sign is very informative; it represents whether a given attribute negatively or positively affects the choice of an alternative.

As the conditional logit models are no longer state-of-the-art in choice modelling, this study employs discrete choice models that relax IIA and other assumptions of the MNL and allow the model coefficients to vary over individuals by including stochastic components.

Table A-1 reports the results of the Conditional Logit Model base model. The base model specification contains only DCE attributes and excludes individual-specific variables such as individual characteristics. The second model specification in Table A-2 contains individual-specific characteristics like age, gender, and satisfaction with the electricity supply from the local utility. The χ^2 statistics show that all the estimated models are statistically significant at the one per cent level. All DCE attribute coefficients are statistically significant in the base model, and the attribute coefficient signs are as expected. The non-cost attributes, backup, no pollution and energy trading all have positive coefficients suggesting that respondents prefer homes in estates with cleaner backup options (solar and inverter), no pollution and the ability to trade energy among neighbours. The negative coefficient from the cost parameters means that, as expected, increases in house price and backup price reduce the probability of an alternative being chosen.

[45] It is noted that the multinomial logit (ML) model is like the Conditional Logit (CL) model. By definition, the systematic component of utility in the ML model depends on variables that are specific to the individual (e.g., gender, age, and income), whereas in the CL model, it depends on variables specific to the given alternative. Practically, the systematic component of utility is frequently modelled to be dependent on both individual- and alternative specific variables. Therefore, the model names are frequently confused (Aizaki, Nakatani and Sato, 2014).

Table A-1: Estimation Results, Conditional Logit – Base Model

Attributes	Coeff.	(Std. Err.)
Backup (solar and inverter)	0.172**	0.073
No Pollution	0.764***	0.082
Energy trading (Buying and selling)	0.376***	0.071
House price	-0.014**	0.005
Backup price	-0.725***	-0.097
Alternative Specific Constant (ASC)	2.026***	0.245
N	6,549	
Log-likelihood	-1916.606	
Prob>chi^2	0	
*Significant at 10% **Significant at 5% *** Significant at 1%		

The second estimated model in Table A-2 includes individual-specific variables to derive inferences about the influence of individual characteristics on choice[46]. However, these were insignificant except in the highest income category (above ₦1m). Despite the insignificance of the individual-specific variables, they still convey some interesting findings about the preferences of individuals within the sample. The age coefficient signified that older respondents were more likely to pick a cleaner estate. Regarding gender differences, the results suggest that female respondents within the sample are more likely to select a cleaner option than male respondents. The results for the variable depicting household size were not consistent. In option A, the result is positive, whilst the result is negative in option B. The variable characterising households with children is also positively associated with but also not found to be a significant predictor of house choice. Table A-2 is presented below.

[46] It should be noted that the coefficients of the individual specific variables are estimated compared to the status quo alternative (option C) and are interpreted in this manner

Table A-2: Estimation Results, Conditional Logit – Model 2

Attributes	Coeff.	(Std. Err.)
Backup (solar and inverter)	0.192**	0.08
No Pollution	0.829***	0.09
Energy trading (Buying and selling)	0.413***	0.079
House price	-0.014**	0.006
Backup price	-0.783***	0.105
Individual specific variables		
Age	0.145	0.119
Female	0.506	0.315
Household income (>₦1m)	15.261***	0.095
Household head education	0.15	0.34
Household size	0.033	0.297
Households with children	0.349	0.355
Alternative Specific Constant (ASC)	0.749	1.159
N	5,583	
Log-likelihood	-1592.562	
Prob>chi^2	0	

*Significant at 10% **Significant at 5% *** Significant at 1%

Appendix A2: Interview Participant Information Sheet

Participant Information Sheet

Title of Project: **Assessing consumers' decision to adopt backup solar energy in Nigeria**

You are invited to take part in this research by researchers at the University College London. Before you decide whether to take part, please read this information sheet carefully. If you have any questions, please ask the student researcher on the contact details below.

Name: Ayooluwa Adewole

Work Address: [redacted]

Contact Details [redacted]

What is the research about?

In block of flats and housing estates, having a backup electricity supply from solar energy can be better than having every household using diesel or petrol fired backup generators.

This research seeks to understand the factors that would motivate people to rent a home with backup solar energy instead of using diesel or petrol fired generators in Nigeria.

The study would help us understand how much people want to pay to rent homes with backup solar energy in Nigeria.

Who is conducting the research?

Ayooluwa Adewole is conducting this research as part of his PhD course in the Bartlett School of Environment, Energy and Resources at University College London. Michelle Shipworth, from The Energy Institute, is supervising the research. Ayooluwa is an energy economist with interests in renewable energy and working experience as a research assistant at the Centre for Petroleum, Energy Economics and Law, University of Ibadan, Nigeria.

Why have I been invited?

You have been chosen for this research because you are a real estate agent who is an expert on the housing industry in Nigeria.

Do I have to take part?

It is completely up to you to decide whether or not to take part in this research. You can withdraw your consent at any time. If you withdraw your consent, you do not need to give a reason, and it will not disadvantage you in any way.

What will happen to me if I take part?

If you decide to take part, Ayooluwa Adewole will call you to arrange a convenient time and place to be interviewed. The interview will take between 30 minutes to an hour and will be audio recorded. The audio and/or video recordings will be used only for data analysis, although your words may be quoted for illustration in my dissertation, conference presentations and publications. However, it would not be possible to identify you from the words or sentences quoted. No other use will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings.

What are the possible disadvantages and risks of taking part?

There are no associated risks associated with taking part in this research.

What are the possible benefits of taking part?

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will aid in understanding how much people are interested in renting homes with backup solar power, which can be useful to landlords looking to develop new building projects as well as future marketing strategies to clients of your company.

Will my taking part in the study be kept confidential?

All the information we collect will be treated as confidential and will only be shared with the research team (Ayooluwa Adewole, Michelle Shipworth). Any information that we collect from you will be stored on a secure UCL file store and will be processed in accordance with Data Protection legislation. Your anonymised interview data will be stored separately on a password protected UCL computer. The audio files of the interviews will be destroyed after the study. You will not be able to be identified in any reports or publications [unless you have expressly given your permission to this].

What are the limits to confidentiality?

Assurances on confidentiality will be strictly adhered to unless evidence of wrongdoing or potential harm is uncovered. In such cases, the University may be obliged to contact relevant statutory bodies/agencies.

What will happen to the results of the research?

The main output of this research will be an MPhil/PhD Upgrade Research Report and a PhD Thesis, although it is possible that the results will be included in reports, presentations, and/or academic papers.

Will my or my organisation's identity be revealed in the research outputs?

Your insights will either be summarised or quoted in a way that will not disclose your identity or the identity of your organisation to others outside the study. If there is any chance that the summary or quote could be linked back to you or your organisation, we will check with you before including it in the Dissertation, report, presentation or paper.

Data Protection Privacy Notice

Information collected in this study will be processed only for the purposes outlined in this information sheet and only so long as required for this research project. It will be stored on my UCL Filestore@UCL central file storage and will only be used by me and my supervisory team. The data controller for this project will be University College London (UCL). The UCL Data Protection Office provides oversight of UCL activities involving the processing of personal data. The Data Protection Officer, [redacted] can be contacted at [redacted].

Who can I contact for further information?

If you have questions or want more information on the research, please contact Ayooluwa Adewole on [redacted]

Who can I contact to complain or express my concerns about this research?

If you are concerned about any part of this research or your participation, please contact the Supervisor, the Dissertation Coordinator and/or the Director of Ethics at the UCL Bartlett School of Environment, Energy and Resources:

- **Supervisor:** Michelle Shipworth, [redacted]
- **Energy Institute Ethics Coordinator:** Mike Fell - [redacted]

If you are concerned about how your personal data is being processed, please contact the UCL Data Protection Officer: [redacted]. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO): https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/

Appendix A3: Interview Informed Consent Form

Project Title: Assessing consumers' decision to adopt backup solar energy in Nigeria

Researcher: Ayooluwa Adewole

Supervisor: Michelle Shipworth

Participant's statement:

I confirm that:

- I have read and understood the Participant Information Sheet and had the opportunity to ask questions. ☐
- I understand that participation is entirely voluntary. If I decide I no longer wish to take part in this research, I can withdraw at any time, without giving a reason, and any data I have provided will not be used. ☐
- I agree to be interviewed as outlined on the Participant Information Sheet. ☐
- I agree for the interview to be recorded as outlined on the Participant Information Sheet. ☐
- I understand that the information from this interview will be treated as strictly confidential (only shared with the research team), will be securely stored and will be handled in accordance with Data Protection legislation. ☐
- I understand that quotes or summaries from the interview will not disclose my identity or the identity of my organisation and that if there is any chance that the summary or quote could be linked back to me or my organisation, you will check with me before including it in any output. ☐

Participant's Name ____

Participants Signature ______________________ **Date** ____________________

Researcher's name ____

Researcher's Signature ______________________ **Date** ____________________

Two copies of this form should be signed – one for the participant to keep and one for the researcher.

Appendix A4 Interview Question Guide

The aim of this exploratory Interview Guide is to gather information through interviews and discussions sessions with stakeholders on the adoption of solar PV installations in blocks of flats and urban multi-occupant buildings in Nigeria, as part of a study on the role of the adoption of solar energy in Nigeria.

1. What type of buildings do you have available for clients to rent out?
2. Are they usually such that it is just one household living in the building or numerous households living in the building?
3. What attributes of rental homes do you showcase to your clients?
4. What considerations do your clients (renters) ask about when deciding to rent a home?
5. Do you discuss the sources of backup electricity supply with your clients?
6. How do you think your clients would respond to the possibility of backup electricity?
7. What type of requests do your clients make about energy availability for the house they want to rent?
8. Do your clients discuss the hours of electricity supply they would prefer to have on average in a day?
9. Does the number of hours of electricity supply affect the demand for certain rental locations?
10. What kinds of discussions do you have with clients around the need/possibility of having a backup electricity supply?
11. Do your clients discuss any forms of pollution as a factor when looking out for a place to rent?
12. In your opinion, do you think your clients would be interested in paying higher rents for solar-powered backup energy

Appendix A5: Email/Letter to Interview Participants

Dear ____

My name is Ayooluwa Adewole, and I am a PhD student at University College London in the UCL Energy Institute. I am undertaking research into solar energy adoption among urban Nigerian Households under the supervision of Michelle Shipworth. Given your relevant experience in this field, I would like to invite you to take part in my research.

Before you decide whether or not to take part, please read the attached Participant Information Sheet. It provides a brief overview of the research and explains what participation involves.

If you have any questions before you decide whether or not to take part, please do contact me at [redacted]. If you are concerned with any part of this research or your participation, please contact my Supervisor, and/or Coordinator and/or my Department's Director of Ethics. Their contact details are included in the attached Participant Information Sheet.

Thank you for your time and your consideration.

Kind Regards

Ayooluwa Adewole

Supervisor: Michelle Shipworth

Appendix A6: Survey invitation letter

[redacted]

The Chairman,

____
____
____

Dear Sir/Madam,

REQUEST FOR RESEARCH SURVEY PARTICIPATION

My name is Ayooluwa Adewole, and I am a PhD student at the Energy Institute, University College London. I am undertaking research into solar energy adoption among Nigerian Households living in estates under the supervision of Michelle Shipworth. I would kindly like to administer my survey questionnaire to residents in your estate during the monthly association meetings between June and August 2019.

With your consent, during the meeting, the questionnaires will be distributed to members present, and research assistants will be available to explain or clarify any sections of the questionnaire that may be difficult for participants to understand.

The survey questionnaire will ask residents about their views on various forms of backup electricity such as generators, inverters and solar systems. When filling out the questionnaire, participants will also be tasked with choosing among various homes in an imaginary new estate. Finally, demographic information regarding participants will also be collected with the questionnaires. The questionnaire would take between 15-20 minutes to complete.

However, if certain participants are unable to complete the questionnaire at the meeting, they can take it home after the meeting to complete it. With consent, the research team will then collect mobile phone contact details and arrange a convenient time and pick up the completed questionnaire.

The information from the questionnaire will be used only for data analysis, and findings from the analysis will be presented in my PhD thesis, conference presentations and publications. However, it would not be possible to identify any resident from the analysis. No other use of the information will be made without written permission. Furthermore, no one outside the project will be allowed access to the original questionnaires. The data collected from this study will be strictly confidential, securely stored and protected in line with the European Union's General Data Protection Rules and Guidelines.

If you have any questions further questions regarding this research, please do contact me at [redacted]. If you are concerned with any part of this research or the participation of your estate residents, please contact my Supervisor, Michelle Shipworth [redacted]

Thank you for your time and your consideration.

Kind Regards

Ayooluwa Adewole

Appendix A7: Survey Participant Information Sheet

THE BARTLETT SCHOOL OF ENVIRONMENT, ENERGY AND RESOURCES

Participant Information Sheet

UCL Research Ethics Committee Approval ID Number: Z6364106/2019/05/114 social research

Title of Project: **Adopting Solar PV for Backup Electricity in Nigerian Residential Estates**

You are invited to take part in this study by researchers at the Energy Institute, University College London. Before you decide whether to take part, please read this information sheet carefully. If you have any questions, please ask the student researcher on the contact details below.

Name: Ayooluwa Adewole

Work Address: [redacted]

Contact Details [redacted]

What is the research about?

In block of flats and housing estates, having a backup electricity supply from solar energy can be better than having every home using diesel or petrol fired backup generators because of the noise and smoke from generators.

This research seeks to understand the things that influence people's decisions on getting a home with backup solar energy instead of using diesel or petrol fired generators in Nigeria.

The study would help us understand people's decisions for using backup solar energy in Nigeria.

Who is conducting the research?

Ayooluwa Adewole is conducting this research as part of his PhD in Energy at the Bartlett School of Environment, Energy and Resources at University College London.

Michelle Shipworth, from the UCL Energy Institute, is supervising the research. Ayooluwa is an energy economist with interests in renewable energy and prior experience as a research assistant at the Centre for Petroleum, Energy Economics and Law, University of Ibadan, Nigeria.

Why have I been invited?

You have been chosen for this research because you are living in a residential estate in Ibadan, which is the chosen location for this study.

Do I have to take part?

It is completely up to you to decide whether or not to take part in this research. You can withdraw your consent at any time. If you withdraw your consent, you do not need to give a reason, and it will not disadvantage you in any way.

What will happen to me if I take part?

If you decide to take part, research assistants on this project will join you in your monthly association meeting to administer the questionnaire. When filling out the questionnaire, you will be tasked with making a choice among various homes in a new estate. The questionnaire would take between 15-30 minutes to complete. If you are unable to complete the questionnaire at the meeting, you can take it home after the meeting to complete it. With your consent, the research team will take your mobile phone contact details and arrange a convenient time and pick up the completed questionnaire.

The information from the questionnaire will be used only for data analysis, and findings from the analysis will be presented in my PhD thesis, conference presentations and publications. However, it would not be possible to identify you from the information provided. No other use of the information will be made without your written permission. Furthermore, no one outside the project will be allowed access to the original questionnaires.

What are the possible disadvantages and risks of taking part?
There are no associated risks associated with taking part in this research.

What are the possible benefits of taking part?
Whilst there are no immediate benefits for participating in the project, it is hoped that this work will aid in understanding how much people are interested in renting homes with backup solar power, which can be useful to landlords looking to develop new building projects.

Will my taking part in the study be kept confidential?
All the information that we collect about you during the research will be kept strictly confidential. You will not be able to be identified in any ensuing reports or publications. Any information that we collect from you will be stored on a secure UCL file store and will be processed in accordance with Data Protection legislation. Your anonymised interview data will be stored separately on a password protected UCL computer. You will not be identified in any reports or publications [unless you have expressly given your permission to this].

What are the limits to confidentiality?
Assurances on confidentiality will be strictly adhered to unless evidence of wrongdoing or potential harm is uncovered. In such cases, the University may be obliged to contact relevant statutory bodies/agencies.

What will happen to the results of the research?
The main output of this research will be a PhD Thesis, although it is possible that the results will be included in reports, presentations, and/or academic papers.

Will my identity be revealed in the research outputs?
Your insights and the information in the questionnaire will either be summarised or quoted in a way that will not disclose your identity to others outside the study. If there is any chance that the summary or information could be linked back to you, we will check with you before including it in the PhD thesis, report, presentation or paper.

Data Protection Privacy Notice
Information collected in this study will be processed only for the purposes outlined in this information sheet and only so long as required for this research project. It will be stored on my UCL Filestore@UCL central file storage and will only be used by me and my research team. The data controller for this project will be University College London (UCL). The UCL Data Protection Office provides oversight of UCL activities involving the processing of personal data. The Data Protection Office can be contacted at [redacted].
This 'local' privacy notice sets out the information that applies to this particular study. Further information on how UCL uses participant information can be found in our 'general' privacy notice: For participants in research studies, see https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice
The information that is required to be provided to participants under data protection legislation (GDPR and DPA 2018) is provided across both the 'local' and 'general' privacy notices.
The lawful basis that will be used to process your personal data is 'Public task' for personal data.

Your personal data will be processed so long as it is required for the research project. If we are able to anonymise or pseudonymise the personal data you provide we will undertake this and will endeavour to minimise the processing of personal data wherever possible.

You have certain rights under data protection legislation in relation to the personal information that we hold about you. These rights apply only in particular circumstances and are subject to certain exemptions such as public interest (for example, the prevention of crime). They include:

- The right to access your personal information;
- The right to rectification of your personal information;
- The right to erasure of your personal data;
- The right to restrict or object to the processing of your personal data;
- The right to object to the use of your data for direct marketing purposes;
- The right to data portability;
- Where the justification for processing is based on your consent, the right to withdraw such consent at any time; and
- The right to complain to the Information Commissioner's Office (ICO) about the use of your personal data.

Who can I contact for further information?
If you have questions or want more information on the research, please contact: Ayooluwa Adewole on [redacted]

Who can I contact to complain or express my concerns about this research?
If you are concerned about any part of this research or your participation, please contact the Supervisor, the Dissertation Coordinator and/or the Director of Ethics at the UCL Bartlett School of Environment, Energy and Resources:

- **Supervisor:** Michelle Shipworth, [redacted]
- **Energy Institute Ethics Coordinator:** [redacted]

If you are concerned about how your personal data is being processed, please contact the UCL Data Protection Officer: [redacted]. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO): https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/

Appendix A8: Interview Informed Consent Form

Project Title: Adopting Solar PV for Backup Electricity in Nigerian Residential Estates

Researcher: Ayooluwa Adewole
Supervisor: Michelle Shipworth

Participant's statement:

I confirm that:

- I have read and understood the Participant Information Sheet and had the opportunity to ask questions. ☐
- I understand that participation is entirely voluntary. If I decide I no longer wish to take part in this research, I can withdraw at any time, without giving a reason, and any data I have provided will not be used. ☐
- I agree to fill out the questionnaire as outlined on the Participant Information Sheet. ☐
- I understand that the information from this questionnaire will be treated as confidential (only shared with the research team), will be securely stored and will be handled in accordance with Data Protection legislation. ☐
- I understand that quotes, findings or summaries from the questionnaire will not disclose my identity and that if there is any chance that the summary or quote could be linked back to me, you will check with me before including it in any output. ☐

Participant's Name ____

Participants Signature ______________________ **Date** ____________________

Researcher's name _____________AYOOLUWA ADEWOLE________________

Researcher's Signature ______________________ **Date** ___25/05/2019_____

Two copies of this form should be signed – one for the participant to keep and one for the researcher.

Appendix A9: Survey Questionnaire

SURVEY ON BACKUP ELECTRICITY USE IN NIGERIA **Group A**

Please, this section should be filled by the enumerator		
Date:	Form Number:	
Estate Name:		
Questionnaire status	Completed	☐
	Partially completed	☐
	Refused	☐
	Other (specify)	
Data entry	Complete	☐
	Incomplete	☐

Introduction

The aim of this survey is to determine your preference for backup energy usage and provision. Questions will also be asked about your current use of backup energy. Please ensure to respond to the best of your knowledge. The results from this study can be used to inform the development of relevant alternative electricity improvement projects that are tailored to meet people's preferences. In your answers, please consider the needs of all members of your household. Your responses to this questionnaire will be completely confidential.

PART A: Questions regarding electricity provision

Please answer the following questions regarding your experience with publicly provided and backup energy usage and expenditure			
1	Which of the following backup energy options do you have? *Please select all that apply*	Petrol Generator	☐
		Diesel Generator	☐
		Inverter and batteries	☐
		Solar, inverter and batteries	☐
		None	☐
(If you selected "none" please skip to question 7)			
2	On an average weekday (Mon-Friday), how many hours of backup electricity do you use? *Please select only one answer*	Less than 5 hours	☐
		Between 5-less than 10 hours	☐
		Between 10 hours – less than 15 hours	☐
		Between 15hours – less than 20 hours	☐
		More than 20 hours a day	☐
3	On an average day during the weekend (Saturday or Sunday), how many hours of backup electricity do you use? *Please select only one answer*	Less than 5 hours	☐
		Between 5-less than 10 hours	☐
		Between 10 hours – less than 15 hours	☐
		Between 15hours – less than 20 hours	☐
		More than 20 hours a day	☐
4	How much do you approximately spend on fuelling your generator weekly? *Please select only one answer*	Less than ₦5,000	☐
		Between ₦5,000 to less than ₦10,000	☐
		Between ₦10,000 to less than ₦15,000	☐
		Between ₦15,000 to less than ₦20,000	☐
		Between ₦20,000 to less than ₦25,000	☐
		₦25,000 or more	☐
5	Have you ever turned off your generator due to noise? *Please select only one answer*	Yes	☐
		No	☐

6	Have you ever turned off your generator due to concerns about the exhaust fumes? *Please select only one answer*	Yes	☐
		No	☐
7	On an average weekday (Mon-Friday), how many hours of electricity do you get from IBEDC (NEPA)? *Please select only one answer*	Less than 5 hours	☐
		Between 5-less than 10 hours	☐
		Between 10 hours – less than 15 hours	☐
		Between 15hours – less than 20 hours	☐
		More than 20 hours a day	☐
8	On an average day during the weekend (Saturday or Sunday), how many hours of electricity do you get from IBEDC (NEPA)? *Please select only one answer*	Less than 5 hours	☐
		Between 5-less than 10 hours	☐
		Between 10 hours – less than 15 hours	☐
		Between 15hours – less than 20 hours	☐
		More than 20 hours a day	☐
9	How many hours of electricity supply from IBEDC (NEPA) would you ***prefer*** to have on any given day? *Please select only one answer*	Less than 5 hours	☐
		Between 5-less than 10 hours	☐
		Between 10 hours – less than 15 hours	☐
		Between 15hours – less than 20 hours	☐
		More than 20 hours a day	☐
10	How much do you approximately spend on electricity from IBEDC monthly? *Please select only one answer*	Less than ₦5,000	☐
		Between ₦5,000 to less than ₦10,000	☐
		Between ₦10,000 to less than ₦15,000	☐
		Between ₦15,000 to less than ₦20,000	☐
		Between ₦20,000 to less than ₦25,000	☐
		₦25,000 or more	☐

PART B: Questions regarding the awareness and usage of backup energy.

Please answer the following questions regarding your experience of electricity provision in the current estate where you reside.						
To what extent do you agree with each of the following statements		Disagree	Somewhat disagree	Not sure	Somewhat agree	Agree
11	Electricity availability is a very important consideration for me when I want to buy or build a new home.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
12	I am satisfied with the electricity service provided by IBEDC	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
13	I consider myself to be an environmentally conscious person	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
14	I am satisfied with the stability of the power supply (such as less frequent power outages)	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
15	I am satisfied with the availability and rollout of electricity meters	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Please answer the following questions on your interest in alternative forms of backup energy.						
To what extent do you agree with each of the following statements		Disagree	Somewhat disagree	Not sure	Somewhat agree	Agree
16	I am concerned about the health impacts of using a backup generator	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
17	I have considered buying an inverter and battery storage system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
18	I have considered buying a solar system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

19	I am interested in a steady supply of electricity in my home	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

20	Which of the following reasons do you need to use backup electricity for in your home? *Please select all that apply*	Entertainment (Television, radio, video player etc.)	☐
		Security (e.g., to use security lights at night)	☐
		IT (e.g., Computers, printers)	☐
		Refrigeration (e.g., Fridge or Freezer)	☐
		Cooking (e.g., to use an oven or microwave)	☐
		Cooling (e.g., Air conditioner or fan)	☐
		Domestic maintenance (e.g., Laundry and Ironing)	☐

Please answer the following questions regarding your views on pollution and health risks of using a generator where you reside.

	To what extent do you agree with each of the following statements	*Disagree*	*Somewhat disagree*	*Not sure*	*Somewhat agree*	*Agree*
21	Living in a clean neighbourhood is very important to me.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
22	I am concerned that constant use of generators might affect might my health over time.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
23	I am concerned that noise from generators might affect my hearing and that of my family over time	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
24	I am concerned that noise from generators might affect my neighbours over time	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
25	The exhaust fumes from generators give me concerns regarding my health	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
26	The exhaust fumes from generators give me concerns regarding those in my neighbourhood.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
27	If I could have an affordable alternative that still guarantees electricity supply, I would stop using my generator	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

PART C: Interest in Energy trading

Suppose you had solar panels installed in your house and you have a service; (such as a mobile application on your smartphone or a community-based platform) that allows you to buy and sell excess electricity generated to neighbours. *Please answer the following questions regarding how you would be interested in such energy trading platform by stating the extent to which you agree with each of the following statements.*

	Please select only one option for each question	*Disagree*	*Somewhat disagree*	*Not sure*	*Somewhat agree*	*Agree*
28	I would be interested in buying electricity from this service if it allows me share some of the burden of generating electricity with my neighbours	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
29	I would be interested in selling electricity through this service if it would allow me to make some additional money.	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
30	I would be interested in selling electricity via such service if it guarantees a return on my investment in buying a solar system	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
31	I would be interested in selling electricity on this platform service if it is easy to get paid for the electricity my neighbours purchase from me	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
32	I would be interested in buying electricity from such service if it guarantees me getting electricity at a cost lower than my current expenses on power	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
33	I would be interested in buying electricity from this platform if it allows a constant supply	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

34	I would be interested in selling electricity on this platform if it benefits my close family and friends living in the neighbourhood	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
35	I would be interested in buying electricity from this platform if it means I do not have to rely on the electricity supply from IBEDC	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
36	I would be interested in this service if it is user friendly	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
37	I would be interested in investing in a solar system that allows me to use such a platform	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

PART D: Choosing houses

- Imagine you are buying a house in a new estate.
- The houses vary in terms of the generator types that are allowed
- Some of the estates do not allow petrol/diesel generators; hence there is not much noise and air pollution
- In this estate, you can also buy and sell electricity with people in the estate
- In addition to the price of the house itself, you also need to consider the amount you will pay upfront to buy the ba ckup electricity type you use
- I'm now going to ask you four questions where you select your most preferred house type.

- 36. House type preference question A-1

Attributes of the house	Option A	Option B	Option C
Backup	Inverter	Inverter	Generator
Pollution	None	None	Yes
Energy Trading	Buying	Selling	Not available
House price	₦20M	₦10M	Same price of your home
Backup price	₦1M	₦1M	Same price as your current generator
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

- 37. House type preference question A-2

Attributes of the house	Option A	Option B	Option C
Backup	Inverter	Inverter	Generator
Pollution	Low	None	Yes
Energy Trading	Buying	Buying	Not available
House price	₦20M	₦10M	Same price of your home
Backup price	₦1M	₦1M	Same price as your current generator
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

- 38. House type preference question A-3

Attributes of the house	Option A	Option B	Option C
Backup	Solar	Inverter	Generator
Pollution	None	Low	Yes
Energy Trading	Buying	Buying	Not available
House price	₦10M	₦20M	Same price of your home
Backup price	₦1M	₦1M	Same price as your current generator
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

- 39. House type preference question A-4

Attributes of the house	Option A	Option B	Option C
Backup	Solar	Solar	Generator
Pollution	None	None	Yes
Energy Trading	Selling	Buying	Not available
House price	₦10M	₦10M	Same price of your home
Backup price	₦1M	₦2M	Same price as your current generator
Most preferred type (Choose one among 3)	Option A ☐	Option B ☐	Option C ☐

PART E: Respondents' demographic and psychographic characteristics

Thank you for filling out the questionnaires so far. We would now kindly ask you to provide some information about yourself. *Please select only one option for each question*			
40	Gender	Male	☐
		Female	☐
41	Marital Status	Single (never married)	☐
		Married	☐
		Divorced/Separated	☐
		Widowed	☐
42	Do you have any children living with you/are any children living with you	Yes	☐
		No	☐
43	Age	18- 29	☐
		30 – 39	☐
		40 – 49	☐
		50 – 59	☐
		60 -70	☐
		71 and above	☐
44	Residential area (*Please state the name of the estate where you live)*		
45	Average monthly household income: *Please specify which of the following represents the total monthly income of all the members of your family in (₦) (including yourself*)	Less than ₦100,000	☐
		₦100,000 to less than ₦250,000	☐
		₦250,000 to less than ₦500,000	☐
		₦500,000 to less than ₦750,000	☐
		₦750,000 to less than ₦1million	☐
		₦1million or more	☐
		Prefer not to say	☐
46	Level of education of the household head/ highest level of education in the household.	No formal education	☐
		Primary school	☐
		Secondary school	☐
		Polytechnic	☐
		Professional qualification	☐
		University (Undergraduate)	☐
		University (Postgraduate)	☐
47	Household size: How many people are in your household?	1 Person	☐
		2 people	☐
		3+ People	☐
48	Employment: What is your current form of employment?	Full time	☐
		Part-time	☐
		Employee (salary, wages)	☐
		Employer	☐
		Self-employed	☐
		Unpaid family worker	☐
		Retired	☐

PART F: Respondents' views on the questionnaire and the Discrete Choice Experiment, and the overall survey

Please answer the following questions regarding your experience of filling out this questionnaire. To what extent do you agree with each of the following statement						
		Disagree	*Somewhat disagree*	*Not sure*	*Somewhat agree*	*Agree*
49	The questionnaire was too long for me	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
50	I found the questionnaire interesting	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
51	The questions in the questionnaire were very difficult to understand	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
52	The questions were quite unrealistic/not credible	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
53	I find the questionnaire to be very educational	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
54	*Please list the questions that were particularly difficult to understand? E.g. question 37*					
55	Any other comments					

END OF QUESTIONNAIRE

Appendix A10: Nvivo Interview Theme Codes

Name

- Solar adoption
  - Adoption of solar energy
    - Adoption is gradual
    - Problems with adoption
    - Solar energy adoption being driven by tenants
    - Solar energy adoption by landlords
  - Attributes of solar energy they tell clients
  - Eradicating or replacing generators with Solar energy
  - Importance of educating clients on compromises
  - Important decision makers in adopting solar
  - Landlords sometimes install solar energy if they live in the place or if it is beneficial
  - Negative attitude of landlord towards back-up energy
  - Price estimate for installing solar home system
  - Reasons for solar failure or poor adoption
  - Residents having control of backup electriicity as a reason to adopt
  - Showcasing running fuel costs as a reason to adopt solar PV
  - Trustworthiness

Name

- Category of people renting homes
  - High income
    - High income people renting are mostly temporary or short term residents
  - Low income
  - Middle income
- Other disscussions
  - Aspiration of home ownership in Nigeria
  - Cost of installing the back-up energy
  - Estate agents advertising facilities to tenants
  - importance of behavioural adaptations to energy usage and thermal comfort in homes especially in contexts wh
  - People that want to stay in clean and queit areas
  - Standard of solar products and consumer confidence
- Solar adoption
  - Adoption of solar energy
    - Adoption is gradual
    - Problems with adoption
    - Solar energy adoption being driven by tenants
    - Solar energy adoption by landlords
  - Attributes of solar energy they tell clients

Name

- Landlords providing backup
  - Landlord provides back-up energy but only for basic amenities like security and water
  - Landlords willing but cannot afford
  - Very few landlords provide back-up electricty
- Role of Government
  - After sales services
  - Promoting local solar production
  - Subsidies
  - Training and technical skills
- Service charge included in rent for back up energy
- Tenants attitude towards paying higher rents for clean and quiet back up energy
- Tenants might not want to have back-up electricity in the rent
- Tenants providing back up electricity themselves
  - Provision of energy back-up; sometimes tenant, sometimes landlord
- Use of inverters and battery storage

Category of people renting homes

- High income
  - High income people renting are mostly temporary or short term residents
- Low income

Name

Attributes of rental homes

- Accesibility
- Age of the building
- Amenities
- Building Type
- Electricity
- Facilities
- Location
- Price
- Safety and Security
- Water availability

Back-up electricity provision

- Back up electiricity requests
  - Tenants asking for back-up electricity
  - Tenants asking for electricity availability
  - Tenants asking for specific hours of electricity
- Back-up electicity provision in rent
- Back-up electricity making buildings more attractive
- Landlords providing backup
  - Landlord provides back-up energy but only for basic amenities like security and water

Appendix A11: Additional Post-Estimation Table

Table A-3: Linear regression of MXL on LCL choice probabilities

Variable	Coefficient	(Std. Err.)
LCLCP	1.0098	0.002
Intercept	-0.0033	0.002
N	7,788	
R^2	0.9491	

Appendix A13: Field Work Picture

Figure A-1: Example of Monthly Residential Estate Association Meeting in Ibadan

Source: Field work in Summer 2019