Energy Policy 174 (2023) 113442

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Peer-to-Peer energy trading, independence aspirations and financial benefits among Nigerian households

Ayooluwa Adewole [a,*], Michelle Shipworth [a], Xavier Lemaire [b], Danielle Sanderson [c]

[a] Energy Institute, University College London, Central House, 14 Upper Woburn Place, London, WC1H 0NN, United Kingdom
[b] Institute for Sustainable Resources, University College London, Central House, 14 Upper Woburn Place, London, WC1H 0NN, United Kingdom
[c] The Bartlett School of Planning, University College London, Central House, 14 Upper Woburn Place, London, WC1H 0NN, United Kingdom

ARTICLE INFO

Keywords:
Autarky
Peer to Peer energy trading
Prosumer
Attitudes
Energy community

ABSTRACT

This paper demonstrates how preferences for energy trading are influenced by autarky aspirations and possible financial benefits from energy trading in the form of lower energy expenses and additional income. It presents findings from a survey on preferences for energy trading on a community-based platform within a residential estate setting. The survey included a choice experiment of hypothetical home choices with the possibility of energy trading on a peer-to-peer (P2P) energy trading platform. It also distinguished between preferences for buying and selling. Participants were 649 residents of housing estates in Ibadan, a Nigerian city. According to our logistic regression analysis, willingness to participate in energy trading was influenced by autarky aspirations and financial benefits. The financial benefits that interest respondents include gaining 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. Real estate developers could therefore capitalise on consumers' high levels of interest in the benefits of homes with P2P energy trading capabilities. Nigerian energy policy-makers should put in place structures that support P2P because P2P energy trading can unlock the additional value of solar PV for residential consumers.

1. Introduction

1.1. Background

Three key energy policy goals in developing countries today 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 global, there is still a large access deficit in Africa (World Bank, 2021a). 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.[1] In Nigeria, the number of people without access increased from 83 million in 2010 to 90 million in 2019, representing 12 percent of the global access deficit and about 45 percent of Nigeria's population. 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, 2020). 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 renewable energy, including mini-grids and solar home systems (Federal Government of Nigeria, 2021). The achievement of these targets will require increased scale-up of renewable energy sources and associated battery storage. As solar photovoltaic (PV) and battery prices are expected to decline rapidly, innovative digital technologies are needed to further integrate renewables (IEA, 2020).

* Corresponding author.
E-mail address: a.adewole.17@ucl.ac.uk (A. Adewole).

[1] Nigeria - 90 million; Democratic Republic of the Congo - 70 million; Ethiopia - 58 million respectively. Of the top ten countries, with electricity access deficit globally, eight are in Africa.

https://doi.org/10.1016/j.enpol.2023.113442
Received 28 May 2022; Received in revised form 18 November 2022; Accepted 12 January 2023
Available online 26 January 2023

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

Peer-to-Peer (P2P) energy trading of solar energy among residential energy consumers is one such 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 (IEA, 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 centers 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 et al., 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.

1.3. Study objectives

Given the potential role that renewable energy and P2P energy trading can play in supporting sustainable and reliable energy provision at the residential estate level, this study examines how *financial benefits and autarky aspirations* influence preferences for P2P energy trading in a residential estate setting. Specifically, this study investigates whether; (i) individuals are motivated to trade energy for the financial benefits they can obtain from trading energy within a residential estate setting; and (ii) P2P energy trading can prove attractive in contexts where people want independence from the local energy provider.

1.4. Benefits of P2P energy trading

The P2P energy trading model offers several benefits. P2P energy trading can improve the deployment and flexibility of renewable energy 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 renewable energy 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 information and communications technology (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 renewable energy (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 by efficiently integrating distributed renewable energy resources and providing ancillary services to the power grid (Zhang et al., 2018). In addition, P2P energy trading can also further environmental sustainability by enabling residential consumers to trade surplus energy from renewable energy like solar (Nguyen et al., 2018).

The emerging literature on P2P energy trading has largely covered technical, socio-economic, policy, and regulatory aspects of P2P energy trading, as outlined in Section 2 below. From the supply side, there is an understanding that profitability is key to making P2P energy trading viable (Park and Yong, 2017). While there is evidence in the literature on the technical aspects of P2P energy trading and some evidence from the global South, such as India (Singh et al., 2017, 2018), there is still limited evidence from Africa on the socio-economic aspects, such as consumers' inclination to participate in such systems and the importance of financial benefits for engaging in energy trading. 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.

1.5. Energy independence aspirations

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; H. Liu et al., 2019; Sabadini and Madlener, 2021). Due to broader governance failures in Nigeria, local communities have taken responsibility for other important community infrastructure such as speedbumps, water supply, and streetlights. Therefore, this paper 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 electricity supply in Nigeria, as 74% of surveyed electricity consumers expressed dissatisfaction with electricity supply and 78% received less than 12 h 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.

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, while autonomy deals with how the goal is achieved, in other words, the ability to self-determine one's energy provision (Adams et al., 2021). The concept of autarky in energy preferences has been discussed in the literature primarily in the context of western developed countries (Engelken et al., 2018; Kalkbrenner, 2019; Korcaj et al., 2015; Müller et al., 2011), with little evidence of studies examining this concept in developing countries in the global South. As with other studies, including Ecker et al. (2017); Ecker et al. (2018); Schmidt et al. (2012), this study draws on the conceptual framing of energy autarky by Müller et al. (2011) as a situation in which the energy services used to sustain local consumption, production and exchange of goods and services are based on renewable energy resources available locally. Although Müller et al. (2011) conceptualise energy autarky in a regional context, this study extends it to the residential estate level by considering the independence of energy supply for individuals dwelling in residential estates. We explore whether the autarky benefits from energy trading prove attractive to individuals who seek independence from the grid, which they may, given challenges with inconsistent supply, inadequate metering, estimated billing, and tariff increases, amongst others. Furthermore, this study distinguishes between preferences for buying and selling electricity on a P2P energy trading platform in a residential estate setting.

1.6. Study outline

The remainder of this paper is organised as follows: Section 2 reviews the relevant literature on P2P energy trading, while Section 3 outlines the data and methodological approach employed. Section 4 presents the results from empirical analysis and discusses the results. Finally, in Section 5, policy implications of the study are provided, and this section also concludes the study.

2. Literature review

2.1. A limited number of real-world case studies

In the literature, several review papers have summarised the state of evidence on P2P energy trading and energy prosumers, covering technical, socio-economic, 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 theory, 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 information communication technology (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 the number of published papers in 2018 and 2019. 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 et al. (2020a)).

2.2. Consumer preferences for participating in P2P energy trading

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 and found key 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 with different 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 largely open to participating in P2P energy trading. The key motivating factors were individuals' environmental attitudes, technical interest, and independence aspirations. The authors found that a high willingness to participate in P2P energy trading was primarily driven 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 households 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 that preferred 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. A set of case studies by Sorin et al. (2019) showed that peer-to-peer market structures could effectively yield market outcomes that differ from centralised market structures and optimise consumers' preferences while maximising social welfare.

Ecker et al. (2018) found that emphasis on *autarky aspirations* increased the subjective value of self-generated energy within a local energy network and reduced the likelihood of P2P energy trading. 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.

From the literature review, we find that there is growing, albeit limited, literature on the preferences of individuals to engage in P2P energy trading. Most of the identified consumer survey studies were based on developed countries, with little evidence on developing countries. We also find limited evidence in the literature on the differences in individual 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 the context of unreliable grid supply and the role of community self-consumption and autarky aspirations in addressing individuals' preferences for a reliable supply of electricity in such context.

3. Methods and data

3.1. Stated preference approach

This study employed the stated preference approach, focusing on investigating the value of "non-direct goods", notably interest in P2P energy trading, for which data on actual individual decisions in Nigeria is not readily available. This approach is advantageous given its ability to indicate how individuals will behave in a scenario or situation that is yet to exist within the research context, in this case P2P energy trading. However, this approach does not necessarily represent the actual decisions or behaviour of the respondents. Instead, it describes how the decision-makers state they would behave. Several studies have expressed concerns over the ability of stated preference approaches to predict actual purchase behaviours (Aguilar and Vlosky, 2007; Bull, 2012; Namkung et al., 2017). However, some studies have opined that many of the observed problems with stated preferences can be corrected by careful study design and implementation (Calfee et al., 2001; Carson et al., 2001). A good experimental design ensures that the choices presented mirror decisions that respondents face in real life (Lancsar and Swait, 2014). Hence the importance of preliminary qualitative work to shape attribute design has been emphasised in the literature (Bao et al., 2020; Bridges et al., 2011; Coast et al., 2012; Glumac and Wissink, 2018; Johnston et al., 2017; Kassim, 2016; Vass et al., 2017). This study follows suit by embedding a qualitative process in the development of the survey. The design of the survey was informed by a qualitative phase, drawing on findings from the literature review and exploratory semi-structured interviews with real estate agents in Nigeria. The qualitative phase served the purpose of understanding attributes that residents look out for when deciding on a new home and the nature of backup energy usage in residential buildings.

3.2. Data

Data used in this study is based on a face-to-face survey carried out in summer 2019 among a convenience sample of residents living in housing estates in Ibadan, a Nigerian city. With a population of 3.1 million,[2] Ibadan city is the largest metropolitan geographical area in West Africa, home to 45% of Oyo state's population (World Bank, 2014). The metropolis is made up of the city of Ibadan (Ibadan urban) and surrounding suburban districts (semi-urban Ibadan). Ibadan is also home to various housing estates with residents that often self-organise themselves through estate associations. 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 study. Participants were identified and contacted through 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 survey was initially piloted with a small sample (9 participants) to determine the appropriateness of survey questions and the choice tasks. This was also used to determine the appropriate representation of the attributes and to identify any issues with the paper-based implementation of the survey. This stage was also useful in creating a clear, relatable, relevant and clear choice sets that participant could understand. The surveys were administered to estate residents during monthly estate association meetings between July–August 2019. The data collection was managed in conjunction with UI-LISA, a local statistical laboratory and data collection team at the University of Ibadan. Research assistants from UI-LISA were hired as survey enumerators and handled the questionnaire distribution. In total, 1024 questionnaires were distributed, 655 questionnaires were retrieved and coded into spreadsheets, representing a response rate of 64%. While cleaning the data, six questionnaire responses were dropped from the dataset used for analysis as they were determined to be invalid as the respondents did not provide any responses to the discrete choice experiment section. After this process, 649 questionnaires were valid for analysis, representing 63% of the original questionnaires distributed.

To ensure the reliability of the data collected in this study, 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). 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, demonstrating reliability and internal consistency of the responses to the questions. The section on interest in energy trading had an alpha of 0.92 suggesting relatively high consistency in the responses of participants.

3.3. Questionnaire structure

The survey questionnaire was split into six sections. The first section of the questionnaire started by presenting questions on the use, interest and expenditure related to various forms of backup energy. The second section examined residents' views on pollution and the health risks of using a generator. Here, respondents were presented with warm-up questions to examine their knowledge of the benefits and externalities of using different types of backup energy. The third section examined respondents' interests in energy trading and included a prompt that introduced the concept of P2P energy trading. This section also prepared participants for the hypothetical nature of the buying and selling choices presented in the choice experiment, as respondents were presented with questions about their preferences for buying and selling energy from solar systems installed in their homes.[3] The fourth section contained four choice experiment questions where the options presented to respondents were varied following an orthogonal experimental design. The choice experiment included an attribute on energy trading with buying and selling levels. Before the choice experiment questions, an information prompt was provided to describe the hypothetical choices of getting a house in a new estate. The information prompt described attributes that define the possible characteristics of the new home in a new estate, with emphasis on the energy characteristics, including the possibility of buying and selling energy. The fifth part of the questionnaire collected information on socio-demographic characteristics, including age, income, location, and gender. The demographic data is used to analyse how preference for energy trading is shaped by personal characteristics and examine the heterogeneity of preferences among respondents. The sixth part of the questionnaire presented some debriefing questions to gather views on how respondents found the questionnaire. In the end, a debriefing section checked how respondents found the choice experiment using a Likert scale. A flowchart of the questionnaire structure, which outlines participants' progress through the study, is provided in Fig. 1 below.

3.4. Ethical considerations

The survey received ethical approval from UCL's Research Ethics Committee. Participants (Approval ID Number: Z6364106/2019/05/114 social research). Participants were given the opportunity to read an information sheet written in plain English which outlined 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 taken to protect their data in accordance with relevant data protection legislation. Voluntary consent was sought and interested participants completed a signed an informed consent form and the participants were allowed to withdraw from the study at any time, without giving a reason.

3.5. Empirical analysis methods

To investigate if people are more likely to trade electricity due to *financial benefits,* we focus 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*. We examine 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 Fig. 2 below).

The analysis estimates the effect of variables depicting financial benefits from trading energy and autarky preferences on home choice.[4]

[2] 2013 estimate based on World Bank (2014).

[3] The specific text presented was as follows*: 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.*

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

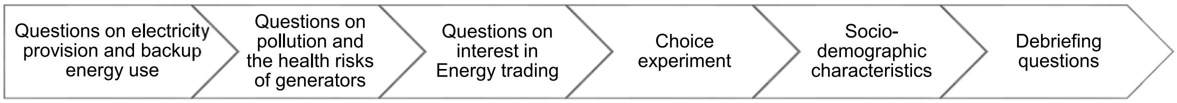

Fig. 1. Outline of the questionnaire structure.

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

Fig. 2. Example of a Choice card presented to study respondents.

We estimate two logistic regression models where the two financial and autarky variables serve as key independent variables. Table 1 outlines the autarky and financial benefit variables alongside the socio-demographic variables included in the model. 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 and 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. 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 confirming and reinforcing the findings.

Table 1
Description of variables used in the model.

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				

4. Results and discussion

4.1. Sample characteristics

Demographic statistics on the proportion of the study sample interested in partaking in energy trading is presented in Table 2. The study sample comprises mainly younger people between 18 and 39 years, representing about 54% of the sample. This group has the largest share of respondents interested in energy trading. Households with three or more people and households living with children are most prominent

Table 2
Sample Summary statistics.

Variable	Description	Share (%)
Interest in energy trading of respondent	Interested in energy trading	91
	Not interested in energy trading	9
Urban: *Depicts if the Household lives in Ibadan Urban Area or the Ibadan Semi-Urban Area*	Ibadan semi-urban area	36
	Ibadan urban area	64
Monthly income of household	Mean income (interval data) NGN	286,284
	Less than N100,000	18
	₦100,000 to less than ₦250,000	31
	₦250,000 to less than ₦500,000	22
	₦500,000 to less than ₦750,000	8
	₦750,000 and above	17
	Prefer not to say	11
Education level of respondent	No University Education	29
	University Education	71
Size of Household	Households with 1–2 people	21
	Households with 3 or more people	79
Children in Household	Households living with children	63
	Households living without children	37
Marital Status of respondent	Married	67
	Single	25
	Other categories	8
Sex of respondent	Male	60
	Female	40
Age of respondent	18–29	27
	30–39	27
	40–49	19
	50–59	13
	60 and above	13

the study sample (79%). This is perhaps due to the nature of the study participants, which was targeted at individuals living in residential estates. Households with monthly income within the range of ₦100,000 (US$325) to less than ₦250,000 (US$815)[5] per month are most common within the sample (31%), while married respondents account for about two-thirds of the sample (67%). About two-thirds of respondents live within the Ibadan urban area (64%), while over a third (36%) reside in the Ibadan semi-urban area. There is also an over-representation of male, highly educated respondents within the sample, and these findings should be noted when considering the results. An overwhelming majority (91%) of participants within the sample indicated an interest in participating in energy trading compared with just 9% of participants that were not interested in energy trading.[6]

4.2. Estimation results

Overall results from the logistic regression analysis revealed that financial benefits and autarky aspirations are key factors influencing participation in energy trading. Results from the logistic regression models[7] are presented in Table 3 below.

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

4.2.1.1. Financial benefits. Starting with the financial benefits variables, most respondents show interest in energy trading to make additional money (82%) and reduce expenses on power (92%) (See Table 2). Results from the empirical analysis show 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 is 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% 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 expenses on power. In percentage terms, the results show that the odds of respondents being interested in P2P energy trading to reduce overall power expenses is 43% higher than the odds of having no interest in P2P energy trading in the buying regression and 25% 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 (Hackbarth and Löbbe, 2020; Karami and Madlener, 2022; Mengelkamp et al., 2019; Palm, 2018).

4.2.1.2. Autarky preferences. From Table 2, it is evident that most respondents are interested in the independence benefit of P2P energy trading in the form of reduced reliance on grid electricity supply (88%). The regression results in Table 3 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% more likely to choose a home with the option to buy P2P electricity, while the odds are 17% 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 et al. (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 "*constant power supply*" does not have a statistically significant effect on choosing a home with energy trading capabilities,[8] despite the descriptive results showing high levels of interest in energy trading to get constant power supply (93%). 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; H. Liu et al., 2019; Sabadini and Madlener, 2021).

4.2.2. 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 is 125% higher than smaller households (with two or fewer individuals). Similarly, the odds for interest in selling energy is 74% 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 (Hahnel et al., 2020; Mengelkamp et al., 2019).

Similarly, we find that households living with children are more likely to be interested in buying and selling aspects of energy trading than respondents not living with children. The odds of households living with children is 111% higher in the buying regression and 61% 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 ranging needs for power within the household.

We find sex-based differences in P2P energy buying preferences; female respondents are more likely to select a home with the option of

[5] 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.

[6] The energy trading indicator was constructed by examining the choices of households in the discrete choice experiment section of the questionnaire. Respondents that selected the status quo option with homes without the possibility of engaging in energy trading are considered as not interested in energy trading. Alternatively, respondents that selected homes where energy trading was a possibility are considered to be interested in energy trading.

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

[8] Collinearity checks were conducted on the *constant power supply* variable and other variables used in the estimated models, 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 were above 2 (the *constant power supply* variable VIF 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 3
Estimation results.

	Choose a home with Buying Option				Choose a home with Selling Option			
VARIABLES	Coefficient	Std Err	Odds ratio	%	Coefficient	Std Err	Odds ratio	%
Additional money	0.219**	(0.087)	1.2473	24.5	0.218***	(0.060)	1.2437	24.4
Lower expenses	0.360*	(0.192)	1.3171	43.3	0.221**	(0.103)	1.2467	24.7
Reduce reliance	1.187***	(0.227)	2.5447	227.7	0.154*	(0.084)	1.1665	16.6
Constant supply	0.267	(0.247)	1.1914	30.5	0.165	(0.127)	1.1792	17.9
Individual specific variables								
Household size: 3+ people	0.813***	(0.283)	1.3806	125.4	0.553***	(0.174)	1.738	73.8
Children	0.748**	(0.351)	1.4304	111.2	0.479**	(0.230)	1.6139	61.4
Female	0.573***	(0.124)	1.3228	77.3	−0.056	(0.092)	0.9455	−5.5
Age: 18–29 (reference category)								
Age: 30-39	0.473**	(0.191)	1.2373	60.5	0.056	(0.120)	1.0575	5.7
Age: 40-49	1.075***	(0.200)	1.5288	193	0.002	(0.137)	1.0017	0.2
Age: 50-59	0.870***	(0.212)	1.3392	138.6	0.019	(0.153)	1.019	1.9
Age: 60 and above	0.771***	(0.239)	1.2899	116.2	−0.150	(0.160)	0.861	−13.9
Household income: Less than ₦100,000 (reference category)								
Household income: ₦100,000 to less than ₦250,000	0.409*	(0.216)	1.2149	50.5	−0.076	(0.124)	0.9271	−7.3
Household income: ₦250,000 to less than ₦500,000	0.792***	(0.220)	1.4197	120.9	−0.050	(0.132)	0.9516	−4.8
Household income: ₦500,000 to less than ₦750,000	1.107***	(0.260)	1.3818	202.7	−0.026	(0.177)	0.974	−2.6
Household income: ₦750,000 and above	1.178***	(0.257)	1.433	224.8	−0.517***	(0.190)	0.5965	−40.3
University Education	0.356**	(0.160)	1.1655	42.8	0.259**	(0.108)	1.2961	29.6
Estimation Statistics								
Observations	2997				3175			
LR chi2(16)	228.32				106.43			
Prob > chi2	0.000				0			
Log likelihood	−939.58				−1610.174			

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

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 is 66% 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 buying energy is higher for all income categories compared with the reference category (which is the lowest income bracket comprising of 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 is on average 150% 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.[9] 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 is 40% 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 is higher for university-educated individuals than non-university educated respondents within the sample. In percentage terms, the odds are 43% higher in the buying analysis and 30% 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.

5. Conclusion and policy implications

P2P energy trading has emerged in recent years 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 study contributes to an

[9] 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.

emerging evidence base by examining the likely financial benefits and energy independence afforded by P2P energy trading; studies on this topic are important because they are so limited. Moreover, the few studies conducted thus far have mostly been conducted in western developed countries. Thus, this study'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 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 gaining 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. Our findings have important implications for industry, policy, and academia as outlined below.

First, to advance P2P energy trading, further research on the economic, legal, regulatory and technological aspects of P2P energy trading is needed in Nigeria. The 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 complements evidence in the literature of interest of residential consumers to reduce dependence on utility supply (Agnew and Dargusch, 2017; Bronski et al., 2014; Fares and Webber, 2017; Hanser et al., 2017; Syed et al., 2020). 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 willingness to pay estimates for P2P energy trading in Nigeria is 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.

Second, our findings show that P2P energy trading can unlock additional benefits from standalone solar PV, in the form of financial and independence benefits, and supply flexibility. This can foster increased interest in 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.

Furthermore, the findings point the role of P2P energy trading as an option in addressing electricity access. Given the increasingly important role of digital technology in the power sector, it is therefore 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 digitisation in its renewable energy sector (Puig et al., 2021). The country's policymakers can further harness this potential by developing and implementing a digitisation roadmap for the energy sector. Such an energy sector digitisation 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.

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 then target those homebuyers that this study found are particularly interested in buying electricity via P2P energy trading: women, families, university graduates, and more affluent residents. An effective marketing strategy would highlight the value that these prospective prosumers would *lose* if they missed out on P2P energy trading. 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. Furthermore, equipping homes with the possibility of P2P energy trading could have some implications on property values. Whilst there would be some cost implications, such as the installation of smart meters in the homes and the development of a technologically enabled trading platform (i.e., using blockchain technology), property developers could benefit from such properties becoming more attractive to prospective homeowners interested in participating in energy trading as found in this study.

Funding

The Ph.D. research underlying this study was supported with partial funding from BP (REF: CID-2489059), which the authors gratefully acknowledge. The funding source had no such involvement in the collection, analysis and interpretation of data; in the writing and in the decision to submit the article for publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Acknowledgements

The authors would like to acknowledge participants at the 2021 EPSRC Centre in Energy Resilience and the Built Environment (ERBE) and London-Loughborough EPSRC Centre for Doctoral Training in Energy Demand (LoLo) Colloquium. Useful comments from Adesola Sunmoni, Sheriff Badmus, Muez Ali are also acknowledged. The authors also thank the anonymous reviewers and the journal editors for critical and productive comments that have improved this paper. All errors are those of the authors.

References

Ableitner, L., Tiefenbeck, V., Meeuw, A., Wörner, A., Fleisch, E., Wortmann, F., 2020. User behavior in a real-world peer-to-peer electricity market. Appl. Energy 270. https://doi.org/10.1016/j.apenergy.2020.115061.

Adams, S., Brown, D., Álvarez, J.P.C., Chitchyan, R., Fell, M.J., Hahnel, U.J.J., Hojckova, K., Johnson, C., Klein, L., Montakhabi, M., Say, K., Singh, A., Watson, N., 2021. Social and economic value in emerging decentralized energy business models: a critical review, 2021 Energies 14. https://doi.org/10.3390/EN14237864, 7864 14, 7864.

Agnew, S., Dargusch, P., 2017. Consumer preferences for household-level battery energy storage. Renew. Sustain. Energy Rev. 75, 609–617. https://doi.org/10.1016/J.RSER.2016.11.030.

Aguilar, F.X., Vlosky, R.P., 2007. Consumer willingness to pay price premiums for environmentally certified wood products in the. U.S. For. Policy Econ. 9, 1100–1112. https://doi.org/10.1016/j.forpol.2006.12.001.

Bao, Q., Sinitskaya, E., Gomez, K.J., MacDonald, E.F., Yang, M.C., 2020. A human-centered design approach to evaluating factors in residential solar PV adoption: a survey of homeowners in California and Massachusetts. Renew. Energy 151, 503–513. https://doi.org/10.1016/j.renene.2019.11.047.

Bridges, J.F.P., Hauber, A.B., Marshall, D., Lloyd, A., Prosser, L.A., Regier, D.A., Johnson, F.R., Mauskopf, J., 2011. Conjoint analysis applications in health—a checklist: a report of the ISPOR good research practices for conjoint analysis task force. Value Health 14, 403–413. https://doi.org/10.1016/J.JVAL.2010.11.013.

Bronski, P., Creyts, J., Guccione, L., Madrazo, M., Mandel, J., Rader, B., Seif, D., Lilientha, P., Glassmire, J., Abromowitz, J., 2014. The Economics of Grid Defection.

Bull, J., 2012. Loads of green washing-can behavioural economics increase willingness-to-pay for efficient washing machines in the UK? Energy Pol. 50, 242–252. https://doi.org/10.1016/j.enpol.2012.07.001.

Calfee, J., Winston, C., Stempski, R., 2001. Econometric issues in estimating consumer preferences from stated preference data: a case study of the value of automobile travel time. Rev. Econ. Stat. 83, 699–707. https://doi.org/10.1162/003465301753237777.

Carson, R.T., Flores, N.E., Meade, N.F., 2001. Contingent valuation: controversies and evidence. Environ. Resour. Econ. 19, 173–210. https://doi.org/10.1023/A:1011128332243.

Climate Action Tracker, 2021. Nigeria net zero targets - climate action tracker [WWW Document]. URL. https://climateactiontracker.org/countries/nigeria/net-zero-targets/ (accessed 12.5.21).

Coast, J., Al-Janabi, H., Sutton, E.J., Horrocks, S.A., Vosper, A.J., Swancutt, D.R., Flynn, T.N., 2012. Using qualitative methods for attribute development for discrete choice experiments: issues and recommendations. Health Econ. 21, 730–741. https://doi.org/10.1002/hec.1739.

De Vaus, D., 2002. Analyzing Social Science Data: 50 Key Problems in Data Analysis. Sage.

Ecker, F., Hahnel, U.J.J., Spada, H., 2017. Promoting decentralized sustainable energy systems in different supply scenarios: the role of autarky aspiration. Front. Energy Res. 14. https://doi.org/10.3389/FENRG.2017.00014, 0.

Ecker, F., Spada, H., Hahnel, U.J.J., 2018. Independence without control: autarky outperforms autonomy benefits in the adoption of private energy storage systems. Energy Pol. 122, 214–228. https://doi.org/10.1016/j.enpol.2018.07.028.

Einav, L., Farronato, C., Levin, J., 2016. Peer-to-Peer markets. Annu. Rev. Econom. 8, 615–635. https://doi.org/10.1146/annurev-economics-080315-015334.

Engelken, M., Römer, B., Drescher, M., Welpe, I., 2018. Why homeowners strive for energy self-supply and how policy makers can influence them. Energy Pol. 117, 423–433. https://doi.org/10.1016/J.ENPOL.2018.02.026.

Esmat, A., de Vos, M., Ghiassi-Farrokhfal, Y., Palensky, P., Epema, D., 2021. A novel decentralized platform for peer-to-peer energy trading market with blockchain technology. Appl. Energy 282, 116123. https://doi.org/10.1016/J.APENERGY.2020.116123.

Fares, R.L., Webber, M.E., 2017. The impacts of storing solar energy in the home to reduce reliance on the utility. Nat. Energy 22 (2), 1–10. https://doi.org/10.1038/nenergy.2017.1, 2017.

Federal Government of Nigeria (FGN), 2021. Nigeria's Nationally Determined Contribution.

Glumac, B., Wissink, T.P., 2018. Homebuyers' preferences concerning installed photovoltaic systems. J. Eur. Real Estate Res. 11, 102–124. https://doi.org/10.1108/JERER-12-2016-0044.

Hackbarth, A., Löbbe, S., 2020. Attitudes, preferences, and intentions of German households concerning participation in peer-to-peer electricity trading. Energy Pol. 138, 111238 https://doi.org/10.1016/j.enpol.2020.111238.

Hahnel, U.J.J., Herberz, M., Pena-Bello, A., Parra, D., Brosch, T., 2020. Becoming prosumer: revealing trading preferences and decision-making strategies in peer-to-peer energy communities. Energy Pol. 137, 111098 https://doi.org/10.1016/j.enpol.2019.111098.

Hanser, P., Lueken, R., Gorman, W., Mashal, J., 2017. The practicality of distributed PV-battery systems to reduce household grid reliance. Util. Pol. 46, 22–32. https://doi.org/10.1016/J.JUP.2017.03.004.

IEA, 2020. World Energy Outlook 2020.

Johnston, R.J., Boyle, K.J., Adamowicz, V., Bennett, J., Brouwer, R., Cameron, T.A., Hanemann, W.M., Hanley, N., Ryan, M., Scarpa, R., Tourangeau, R., Vossler, C.A., 2017. Contemporary Guidance for Stated Preference Studies. https://doi.org/10.1086/691697.

Kalkbrenner, B.J., 2019. Residential vs. community battery storage systems – consumer preferences in Germany. Energy Pol. 129, 1355–1363. https://doi.org/10.1016/J.ENPOL.2019.03.041.

Karami, M., Madlener, R., 2022. Business models for peer-to-peer energy trading in Germany based on households' beliefs and preferences. Appl. Energy 306, 118053. https://doi.org/10.1016/j.apenergy.2021.118053.

Kassim, L., 2016. The Revenue Implication of Trade Liberalisation in Sub-Saharan Africa: Some New Evidence. School of Economics Discussion Papers.

Korcaj, L., Hahnel, U.J.J., Spada, H., 2015. Intentions to Adopt Photovoltaic Systems Depend on Homeowners' Expected Personal Gains and Behavior of Peers. https://doi.org/10.1016/J.RENENE.2014.10.007.

Lancsar, E., Swait, J., 2014. Reconceptualising the external validity of discrete choice experiments. Pharmacoeconomics 32, 951–965. https://doi.org/10.1007/s40273-014-0181-7.

Liu, H., Azuatalam, D., Chapman, A.C., Verbič, G., 2019. Techno-economic feasibility assessment of grid-defection. Int. J. Electr. Power Energy Syst. 109, 403–412. https://doi.org/10.1016/J.IJEPES.2019.01.045.

Liu, Y., Wu, L., Li, J., 2019. Peer-to-peer (P2P) Electricity Trading in Distribution Systems of the Future. https://doi.org/10.1016/J.TEJ.2019.03.002.

Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., Weinhardt, C., 2017. Designing microgrid energy markets: a case study: the Brooklyn Microgrid. Appl. Energy. https://doi.org/10.1016/j.apenergy.2017.06.054.

Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., Weinhardt, C., 2018. A blockchain-based smart grid: towards sustainable local energy markets. Comput. Sci. Res. Dev. 33, 207–214. https://doi.org/10.1007/s00450-017-0360-9.

Mengelkamp, E., Schönland, T., Huber, J., Weinhardt, C., 2019. The value of local electricity - a choice experiment among German residential customers. Energy Pol. 130, 294–303. https://doi.org/10.1016/J.ENPOL.2019.04.008.

Müller, M.O., Stämpfli, A., Dold, U., Hammer, T., 2011. Energy autarky: a conceptual framework for sustainable regional development. Energy Pol. 39, 5800–5810. https://doi.org/10.1016/j.enpol.2011.04.019.

Namkung, Y., Jang, S., Shawn, 2017. Are consumers willing to pay more for green practices at restaurants? J. Hospit. Tourism Res. 41, 329–356. https://doi.org/10.1177/1096348014525632.

Nguyen, S., Peng, W., Sokolowski, P., Alahakoon, D., Yu, X., 2018. Optimizing rooftop photovoltaic distributed generation with battery storage for peer-to-peer energy trading. Appl. Energy 228, 2567–2580. https://doi.org/10.1016/J.APENERGY.2018.07.042.

Odutola, A., 2021. World Bank: 62% of Nigerian power consumers believe sector is inefficiently managed - Nairametrics. Nairametrics. https://nairametrics.com/2021/04/25/world-bank-62-of-nigerian-power-consumers-believe-sector-is-inefficiently-managed/.

Orcutt, M., 2017. How Blockchain Could Give Us a Smarter Energy Grid - MIT Technology Review [WWW Document]. MIT Technol. Rev. URL. https://www.technologyreview.com/s/609077/how-blockchain-could-give-us-a-smarter-energy-grid/ (accessed 11.25.17).

Palm, J., 2018. Household installation of solar panels – Motives and barriers in a 10-year perspective. Energy Pol. 113, 1–8. https://doi.org/10.1016/J.ENPOL.2017.10.047.

Park, C., Yong, T., 2017. Comparative review and discussion on P2P electricity trading. In: Energy Procedia. https://doi.org/10.1016/j.egypro.2017.09.003.

Puig, D., Moner-Girona, M., Kammen, D.M., Mulugetta, Y., Marzouk, A., Jarrett, M., Hailu, Y., Nakićenović, N., 2021. An action agenda for Africa's electricity sector. Science 80, 616–619. https://doi.org/10.1126/SCIENCE.ABH1975/ASSET/BAAD5740-5316-431F-8B0A-A4761D07D8FD/ASSETS/IMAGES/LARGE/SCIENCE.ABH1975-F2.JPG, 373.

Reuter, E., Loock, M., 2017. Empowering Local Electricity Markets : A Survey Study from Switzerland (Norway, Spain and Germany).

Sabadini, F., Madlener, R., 2021. The Economic Potential of Grid Defection of Energy Prosumer Households in Germany. Adv. Appl. Energy 100075. https://doi.org/10.1016/J.ADAPEN.2021.100075.

Schmidt, J., Schönhart, M., Biberacher, M., Guggenberger, T., Hausl, S., Kalt, G., Leduc, S., Schardinger, I., Schmid, E., 2012. Regional energy autarky: Potentials, costs and consequences for an Austrian region. Energy Pol. 47, 211–221. https://doi.org/10.1016/J.ENPOL.2012.04.059.

Singh, A., Strating, A.T., Romero Herrera, N.A., Mahato, D., Keyson, D.V., van Dijk, H.W., 2018. Exploring peer-to-peer returns in off-grid renewable energy systems in rural India: An anthropological perspective on local energy sharing and trading. Energy Res. Social Sci. 46, 194–213. https://doi.org/10.1016/J.ERSS.2018.07.021.

Singh, A., Strating, A.T., Romero Herrera, N.A., van Dijk, H.W., Keyson, D.V., 2017. Towards an ethnography of electrification in rural India: Social relations and values in household energy exchanges. Energy Res. Social Sci. 30, 103–115. https://doi.org/10.1016/J.ERSS.2017.06.031.

Sorin, E., Bobo, L., Pinson, P., 2019. Consensus-Based Approach to Peer-To-Peer Electricity Markets with Product Differentiation. https://doi.org/10.1109/TPWRS.2018.2872880.

Soto, E.A., Bosman, L., Wollega, E.D., Leon-Salas, W., 2020. Peer-to-peer Energy Trading: A Review of the Literature. https://doi.org/10.1016/j.apenergy.2020.116268.

Sousa, T., Soares, T., Pinson, P., Moret, F., Baroche, T., Sorin, E., 2019. Peer-to-peer and community-based markets: A comprehensive review. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2019.01.036.

Syed, M.M., Morrison, G.M., Darbyshire, J., 2020. Shared Solar and Battery Storage Configuration Effectiveness for Reducing the Grid Reliance of Apartment Complexes, 2020 Energies 13. https://doi.org/10.3390/EN13184820, 4820 13, 4820.

Tushar, W., Saha, T.K., Yuen, C., Morstyn, T., McCulloch, M.D., Poor, H.V., Wood, K.L., 2019. A motivational game-theoretic approach for peer-to-peer energy trading in the smart grid. Appl. Energy 243, 10–20. https://doi.org/10.1016/J.APENERGY.2019.03.111.

Tushar, W., Saha, T.K., Yuen, C., Smith, D., Poor, H., 2020a. Peer-to-Peer Trading in Electricity Networks: an Overview. https://doi.org/10.1109/TSG.2020.2969657.

Tushar, W., Yuen, C., Mohsenian-Rad, H., Saha, T., Poor, H., Wood, K.L., 2018. Transforming Energy Networks via Peer-To-Peer Energy Trading: the Potential of Game-Theoretic Approaches. https://doi.org/10.1109/MSP.2018.2818327.

Tushar, W., Yuen, C., Saha, T., Morstyn, T., Chapman, A.C., Alam, M.J.E., Hanif, S., Poor, H., 2020b. Peer-to-Peer Energy Systems for Connected Communities: A Review of Recent Advances and Emerging Challenges. https://doi.org/10.1016/j.apenergy.2020.116131.

UNFCCC, 2020. ME SOLshare: Peer-to-Peer Smart Village Grids | Bangladesh [WWW Document]. United Nations Framew. Conv. Clim. Chang. URL. https://cop23.unfccc.int/climate-action/momentum-for-change/ict-solutions/solshare (accessed 5.15.21).

Vass, C., Rigby, D., Payne, K., 2017. The Role of Qualitative Research Methods in Discrete Choice Experiments: A Systematic Review and Survey of Authors. Med. Decis. Making 37, 298–313. https://doi.org/10.1177/0272989X16683934.

Wang, N., Verzijlbergh, R., Heijnen, P., Herder, P., 2020. Modeling the Decentralized Energy Investment and Operation in the Prosumer Era: a Systematic Review. https://doi.org/10.1109/ISGT-Europe47291.2020.9248838.

Wilkinson, S., Hojckova, K., Eon, C., Morrison, G.M., Sandén, B., 2020. Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia. Energy Res. Social Sci. 66, 101500 https://doi.org/10.1016/J.ERSS.2020.101500.

World Bank, 2021a. TRACKING SDG7 A Joint Report of the Custodian Agencies.

World Bank, 2021b. Official exchange rate (LCU per US$, period average) - Nigeria | Data [WWW Document]. World Bank Databank. URL. https://data.worldbank.org/indicator/PA.NUS.FCRF?locations=NG (accessed 3.21.21).

World Bank, 2020. Nigeria - Power Sector Recovery Operation (English) [WWW Document]. URL. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/991581593223433078/nigeria-power-sector-recovery-operation (accessed 2.28.22).
World Bank, 2014. Nigeria. Ibadan Urban Flood Management Project, Washington, DC.
Zhang, C., Wu, J., Long, C., Cheng, M., 2017. Review of Existing Peer-to-Peer Energy Trading Projects. In: Energy Procedia. Elsevier Ltd, pp. 2563–2568. https://doi.org/10.1016/j.egypro.2017.03.737.
Zhang, C., Wu, J., Zhou, Y., Cheng, M., Long, C., 2018. Peer-to-Peer Energy Trading in a Microgrid. https://doi.org/10.1016/J.APENERGY.2018.03.010.
Zhou, Y., Wu, J., Long, C., Ming, W., 2020. State-of-the-Art Analysis and Perspectives for Peer-To-Peer Energy Trading. https://doi.org/10.1016/j.eng.2020.06.002.