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# Gender and ethnic disparities in energy poverty: The case of South Africa

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ABSTRACT

The study ascertained the differentiated energy poverty of female-headed households based on their race/ethnicity in South Africa. The study made use of the 2016 General Household Survey (GHS). A sample of 7322 male-headed households and 6170 female-headed households was utilised. An Energy Vulnerability Index (EVI), Independent *t*-test and Propensity Score Matching (PSM) were used to analyse the data. The results show that male-headed households had more exposure, adaptive capacity and sensitivity to energy poverty compared to female-headed households. Overall, female-headed households were more vulnerable to energy poverty. Compared to White, Indian/Asian and Coloured female-headed households, Black/African female-headed households exhibited more vulnerability to energy poverty. The study concludes that gender of the household head and race/ethnicity of the female-headed households had impact on the energy poverty in South Africa. The study recommends the need to identify relevant gender and race/ethnic issues concerning energy. Furthermore, there is need to counter gendered-ethnic disparities in renewable energy programmes for poorer households, to avail alternative energy sources. Energy policy such as the Free Basic Electricity, besides being pro-poor, should also consider gender and the ethnic divide. Economic opportunities for low income female-headed households should also be promoted to reduce vulnerability to energy poverty.

## 1. Introduction

*Energy poverty* refers to the inadequate access to affordable modern and/or sustainable energy services, a definition mostly utilised in developing countries measured through availability (Castaño-rosa et al., 2019b; Crentsil et al., 2019). In developed countries, the term *fuel poverty* is utilised, referring to insufficient monetary resources to pay for energy needs, measured through affordability. However, both terms are related to energy vulnerability, where individuals become incapable of securing, socially and materially, the level of energy service required in the home (Castaño-rosa et al., 2019b). Middlemiss and Gillard (2015) postulate that households exhibit various degrees of vulnerability based on their exposure, sensitivity and adaptive capacity. This will include "the likelihood of a household being subject to [energy] poverty, the sensitivity of that household to [energy] poverty, and the capacity that household has to adapt to changes in [energy] poverty."

One of the biggest challenges in the 21st century is energy poverty, It affecting vulnerable members of society (Papada and Kaliampakos, 2019). A report by the UN (2019) indicated that 90% of people worldwide have access to electricity. However, 3 billion people worldwide lack clean cooking fuels and technologies (UN, 2019). The report was however silent on equitable access to energy for women. In addition, there were no race and ethnicity issues. Currently, 842.47 million in sub-Saharan Africa (SSA) are without access to clean electricity to cook. Furthermore, 87% of the 842.47 million people without electricity live in rural areas, and mostly are female-headed households. When energy is scarce, the girl child over the boy child is burdened with providing the energy, thus withdrawn from school and becoming illiterate. Illiterate women usually have more children, larger and poorer families reinforcing the cycle of poverty (Fatona et al., 2013). For poor people, the energy problem is associated with lack of energy, but for women it is burdened by social dynamics, power relations and lack of access and control. Women in developing countries spend approximately 2–9 h a day collecting fuel and fodder, and performing cooking chores. The opportunity cost is the income-generating activities that are foregone. Due to their socially determined gender roles, girls and women assume, proportionally, a higher burden of energy services and energy use inefficiency (Fatona et al., 2013).

Ethnicity and inequality are amongst the potential barriers that may impede or slow down energy security (Hanger et al., 2016). Race/ethnic

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diversities can either enhance or hinder development, thus influencing the state of energy security within developing countries (Churchill et al., 2020; David et al., 2018) especially in African countries deemed globally as the most ethnically diverse (Fisher, 2013; Wee, 2019). The importance of social cohesion in energy security in order to promote an inclusive economy is also documented in some international literature (Genys, 2016; Koulouri and Mouraviev, 2019). In South Africa, poverty is consistently highest among Blacks/Africans, the less educated, the unemployed, female-headed households, large families and children (David et al., 2018). Building a cohesive society requires putting more emphasis on reducing poverty, inequalities, social divisions and exclusions (DAC, 2012; DoP, 2012). However, empirical research that analyses the potential influence of ethnicity and inequality on energy security is still limited.

Policy encouraging women participation to realise full human potential in South Africa is encompassed in the country's National Development Plan (NDP) and National Constitution.[1] Equally, the country enacted policy committing to promote access to affordable, clean and sustainable energy services.[2] However, in the 2017 SDG baseline report, South Africa does not mention how it is reforming to provide women equal rights to economic and energy resources (StatsSA, 2017). Equally also, policies do not dwell on gender and race/ethnicity issues (Chikulo, 2014). There are social and historical motives for gender discrepancy in the energy sector and workforce (Hanger et al., 2016). Since the dispensing of the World Bank's 2012 World Development Report: Gender Equality and Development, women have come to be considered as significant drivers in moving to sustainable energy practices and attaining economic growth (Wong, 2012).

The objective of this study was to ascertain the differentiated energy poverty of female-headed households based on race/ethnicity in South Africa. Literature on the intersectionality of energy, gender and ethnicity is scanty. In order to understand energy poverty, more investigations are essential into how different hierarchies of privilege (including ethnicity, inequality and gender) create social differentiation. This necessity has become imminent due to the global issues of climate change and rising economic inequality (Brown and Spiegel, 2019; Lieu et al., 2020). According to Listo (2018), energy is intertwined with social power relations, expressed through gender. There is a need to transgress from holistic interventions or alternatives for energy-gender-poverty because of the differentiated lived experiences. The gender discourse has been co-opted in academic literature to support an agenda for energy development, strengthening the advocacy for energy projects, funding and interventions. This has been at the detriment of gender development (Listo, 2018). On the other hand, race/ethnicity discourse has centred upon Conflict Theory for example, anticipating increased scarce resource competition along the lines of ethnic differences (Robinson, 2017). This creates antagonism and distrust due to competing for resources. Some groups have organised ethnic and indigenous identities in claiming access to resources as rightful "caretakers" (Lau and Scales, 2016). Thus, one race/ethnic group can have better access to energy resources, thereby having a bearing on energy poverty. The current study expands on Listo (2018) who highlighted the shortcomings of the energy-poverty-gender discourse, where the gender myth is typified on the energy-poor woman who is vulnerable, helpless and oppressed. The current study disentangles this to advocate for differential energy poverty among women based on their racial/ethnic background. Much of the gender-related studies have neglected ethnicity's role, choosing to focus on observable measures of gender inequality and its effect on growth and development (Churchill et al., 2019). Ethnic heterogeneity tends to have an effect on various economic and entrepreneurship activities, having impact on resource allocation, access and use as well as decision making on development in SSA (Churchill, 2017). The current study contributes on two fronts. Firstly, is on gender and ethnic diversity literature which utilises micro-level data and secondly the drivers of vulnerability to energy poverty (Churchill and Smyth, 2020). Furthermore, the study expands on studies that have utilised the vulnerability framework in assessing energy poverty (Ahmad et al., 2021).

## 2. Literature review

Intersectionality between gender and ethnic divide threatens the achievement of the 2030 SDGs. According to UN Women (2018), gender-based discrimination is prevalent across all the dimensions in the Agenda 2030 SDGs. There are more women than men under the age of 40 who are poorer, living on less than US$1.90 per day, with unequal access to and control of resources, augmented by occupational segregation and gender pay gaps in the labour markets. This is compounded by half of the girl adolescents in SSA remaining out of school, underrepresented in leadership positions, experiencing violence and are disproportionately affected by environmental degradation and natural disasters (UN Women, 2018).

There are various studies that have taken silo approaches on energy-gender and energy-ethnicity. Pueyo et al. (2020) assessed the advantages accrued to enterprises based on the energy and gender link in Tanzania. They identified that male entrepreneurs benefit from productive utilisation of electricity, whereas women dominate the productive use of fuels such as wood and charcoal. This is because women have less agency than men who tend to own buildings, have a higher income and patriarchal right to make decisions (Pueyo et al., 2020). In Europe, Łapniewska (2019) confirmed that gender equality was valuable in electricity cooperatives. Furthermore, tradition, technology, education and culture were major impediments to women participation in energy cooperatives (Łapniewska, 2019). Feenstra and Özerol (2021) reviewed the intricacies between energy justice (distributive, recognitional and procedural) and engendering policy (women empowerment, gender mainstreaming and social inclusion). They indicated that spatial aspects of energy injustices and unequal access must be addressed. An alternative pathway framework was used by Lieu et al. (2020) in exploring the gendered nature of energy transitions in Canada, Kenya and Spain, and found that women perspectives were left out whilst male perspectives were dominating.

In the US, Graff et al. (2021) found that White households were less likely to be energy insecure compared to Black and Hispanic households. A review by Johnson et al. (2020) on the intersectionality of energy transitions from a gender, social inclusion and low carbon perspectives indicated that energy interventions on their own cannot achieve gender and social equity. In South Africa, Rathi and Vermaak (2018) focussed on rural electrification and gender, highlighting that benefits from electrification depends on gender roles. Mhlanga and Garidzirai (2020) explored the energy-race nexus in South Africa, and found that race is still significant in the demand of electricity. In a review of the energy-gender-poverty nexus in South Africa, Longe (2020) indicated that the energy poor population consisted of 57% women, who are faced with the task of collecting firewood and other unclean sources of energy. Cannon and Chu (2021) argue that though there is substantial literature on gender, sexuality and feminist in energy research, there is need for transdisciplinary in intersecting social identities and interrogating systematic oppression in energy issues. Furthermore, studies should facilitate innovative methodological approaches.

[1] Constitutional Act (Act No. 108 of 1996) guarantees equal and inalienable rights to men and women. Subsequent policy on gender equality include the Employment Equity Act (Act No. 55 of 1993), Commission on Gender Equality Act (Act No. 39 of 1996), Basic Conditions of Employment Act (Act 75 of 1997), Domestic Violence Act (Act No. 116 of 1998), Promotion of Equality and Prevention of Unfair Discrimination Act (Act No. 4 of 2000) and South African National Policy Framework for Women's Empowerment and Gender Equality of 2000 (Chikulo, 2014).

[2] The White Paper on Energy (1998), The White Paper on the Promotion of Renewable Energy and Clean Energy Development (2002) and the Integrated Energy Plan (2003).

Energy vulnerability is an innovative approach that was utilised by Robinson (2019) focusing on socio-spatial perspective in linking energy poverty and gender in England. Spatial gendered energy vulnerabilities in health and economic activities were more pronounced relative to infrastructure or personal activities. Vulnerability indicators such as age of household occupants, household size, occupation, ethnicity and energy use were used to assess vulnerability to energy poverty. Phillips and Petrova (2021) concurred, identifying that vulnerability to energy poverty entails complex socio-economic relations between energy and various institutional factors. According to Habersbrunner et al. (2020), there are variations in gendered vulnerabilities to energy poverty based on intersection of gender with various socio-economic conditions, including ethnicity. Bouzarovski et al. (2021) framed energy vulnerability by concentrating on practices, needs, energy efficiency, flexibility, affordability and access. In the UK Middlemiss and Gillard(2015) conceptualised the energy vulnerability based on quality of dwelling, cost of energy, household income stability and ill-health. They identified that vulnerability can be measured from exploring the exposure, sensitivity and adaptive capacity to [energy] poverty. Ahmad et al. (2021) used the Intergovernmental Panel on Climate Change (IPCC) framework of vulnerability to measure energy poverty in India. Energy vulnerability indices of 0.31 and 0.34 were obtained from the study with varying degrees of exposure, sensitivity and adaptive capacities. However, the literature exhibits lack of consensus on the framing of energy vulnerabilities and has allowed multiple indicators to be utilised.

Gender and ethnicity studies have failed to consider the intersectionality between the two. Policy makers have treated identity as static, separate and concrete producing distinct inequalities and resource use (Lau and Scales, 2016). According to Cole et al. (2015), in marginalisation, certain groups are systematically disadvantaged or excluded based on ethnicity, making them poor in terms of assets and income, inducing gendered vulnerability. The Intersectionality Theory postulates that utilising gender alone essentialises and homogenises women and men as categories, blurring markers of social identities (Marlow and Dy, 2018). It allows the identification and consideration of the multiplicity of social identity categories shaping the nature of identity (Carrim and Nkomo, 2016). According to Dhamoon (2011), intersectionality simultaneously recognises interaction between institutionalised processes (e.g. culturalization, gendering and racialization) to systems of domination (e.g. colonialism, apartheid, patriarchy and racism). Therefore, this intersectionality means that it is women and girls form the poorest ethnic group with high energy poverty than other women, even girls and women from similar backgrounds (Kabeer, 2015). Not all women are similar in their roles as well as access and control to resources and power in decision-making due to gender relations with ethnicity (AGRA, 2018).

## 3. Methods

The study utilised the 2016 General Household Survey (GHS) secondary data from Statistics South Africa (StatsSA) (StatsSA, 2016) based on accessibility. The GHS was conducted in a cross-sectional survey manner, where it was proportionally stratified, with the initial stage encompassing the selection of primary sampling units (provincial and population attributes), whereas the following stage was the systematic sampling of dwelling units. A total of 233 trained StatsSA survey officers obtained data from 21 228 households from the 9 Provinces of South Africa. Table 1 shows the data that was used in the study.

### *3.1. Sample size and location*

From a total sample size of 21 228, the remaining sample utilised after data cleaning is that shown in Table 2. The sample consisted of 7322 male-headed households and 6170 female-headed households, at a total of 13 492.

### *3.2. Analytical framework*

The analytical framework followed a three-stage process:

i. Energy Vulnerability Index

The study utilised the Energy Vulnerability Index (EVI) as that used by Ahmad et al. (2021). The various indicators from Table 1 were used to construct the EVI. The data was standardised to ensure consistency and comparability when comparing and combining the indicators. The study utilised the Min-Max normalisation method, producing an indicator which falls between a 0–1 range, using the following metrics:

$$\mathrm{Index S_c} = \frac{\mathrm{S_{obs}} - \mathrm{S_{min}}}{\mathrm{S_{max}} - \mathrm{S_{min}}}$$

where $S_{obs}$, $S_{min}$ and $S_{max}$ are the observed, minimum and maximum values of the indicator, respectively. Once standardisation was established, the indicators were combined using equal weighting. Composite scores were calculated for the exposure, adaptive capacity and sensitivity to energy poverty, which were combined to form the vulnerability index. The study utilised actual values for each individual household for $S_{obs}$ to ascertain the indicator. After the standardisation of each indicator, they were averaged utilising the formula below:

$$\mathrm{M_{com}} = \frac{\sum_{i=1}^{n} \mathrm{IndexSci}}{\mathrm{n}}$$

where $\mathrm{M_{com}}$ represents one of the major indicators for the study i.e. exposure, adaptive capacity and sensitivity to energy poverty After the standardisation of each major indicator, the following formula was utilised to obtain the Energy Vulnerability Index (EVI):

$$EVI = (E - A)^{*}S$$

where $E$ represents exposure, $A$ is adaptive capacity and $S$ is sensitivity to energy poverty. The EVI is scaled from 0 (low vulnerability) to 1 (high vulnerability).

ii. T-test for differences in energy vulnerability

An independent $t$-test was used to compare the EVI between male-headed and female-headed households. The same test was also used to compare the EVI between female-headed households from various races/ethnicities. The independent $t$-test follows the following model:

$$t = \frac{m_A - m_B}{\sqrt{\frac{s^2}{n_A} + \frac{s^2}{n_B}}}$$

where $A$ and $B$ represent the groups to be compared i.e. male-headed and female-headed households as well as Black/African female-headed households and various races/ethnic group -headed households. $m_A$ and $m_B$ are the means of the two groups of $A$ and $B$; whilst $n_A$ and $n_B$ are the sizes of the two groups of $A$ and $B$. $s^2$ represents the common variance of the two samples, and is calculated as:

$$s^2 = \frac{\sum (x - m_A)^2 + \sum (x - m_B)^2}{n_A + n_B - 2}$$

The degrees of freedom used in the test are calculated as follows:

$$df = n_A + n_B - 2$$

iii. Propensity Score Matching on energy vulnerability

The Propensity Score Matching (PSM) was used to assess the impact of gender on the EVI based on energy utilisation. The PSM was also used to determine the impact of race/ethnicity of female-headed households on the EVI.

**Table 1**
Data used in the study.

| Variable | Justification | Measurement | Min $S_{min}$ | Max $S_{max}$ | Mean | Std. Dev. |
|---|---|---|---|---|---|---|
| **Exposure – The likelihood of a household being subject to energy poverty** | | | | | | |
| Household head age | The extremely younger and older the household head, the higher the risk to energy poverty (Ruse et al., 2019). This due to lack of employment opportunities and readily liquid assets. Robinson (2019) also used age as an indicator of vulnerability to energy insecurity | Actual number | 13 | 107 | 49.69 | 16.02 |
| Ownership of dwelling | Energy insecurity is less likely to be exhibited by renters in permanent and semi-permanent buildings (Khundi-Mkomba et al., 2021). (Matter, 2016) indicates that physical residential energy insecurity (REI) can manifest when there is unaffordability and inefficiency represented by energy inefficient dwellings. This exposes households to energy vulnerability. | Nominal {1-Rented from private individual; 2-Rented from other; 3-Owmed, but not yet paid off to bank/financial institution; 4-Owned but not yet paid off to private lender; 5-Owne and fully paid off; 6-Occupied rent-free} | 1 | 6 | 3.64 | 1.99 |
| Access to electricity | Reduced access to energy exposes households to energy insecurity (Graff and Carley, 2020). | Binary {1-Yes; 2-No} | 1 | 1 | 1 | 0.00 |
| Electricity complaints | Complaints reflect the reduced access to energy and the increased exposure to energy insecurity | | 1 | 2 | 1.95 | 0.23 |
| Electricity cut for non-payment | Disconnections exposed the households to energy vulnerability due to inability to pay for electricity (Memmott et al., 2021) | | 1 | 2 | 1.45 | 0.89 |
| Household expenditure | A high proportion of household expenditure on energy exposes households to energy insecurity (Khundi-Mkomba et al., 2021). A high household expenditure can have differentiated effects on energy security depending on the proportion that covers energy | Ordinal {1-R0; 2-R1-R199; 3-R200-R399; 4-R400-R799; 5-R800-R1199; 6-R1200-R1799; 7-R1800-R2499; 8-R2500-R4999; 9-R5000-R9999; 10-R10000 or more} | 1 | 10 | 7.22 | 1.98 |
| Domestic worker services | Having extra employees increases the energy needs of the households, thereby exposing them to energy insecurity. However, if the employee is involved in obtaining the energy, then exposure to energy insecurity will be decreased. Provision of unpaid care was provided as an indicator of vulnerability to energy insecurity by Robinson (2019). | Binary {1-Yes; 2-No} | 1 | 2 | 1.10 | 0.30 |
| **Adaptive capacity – The capacity of a household to adapt to changes in energy poverty** | | | | | | |
| Salary/wage/income | Total household income has relationship to source of income, with most income emanating from salaries or wages. Energy insecurity is a concern for low income populations (Memmott et al., 2021). Having access to high paying income sources enables households to adapt to instances of energy poverty, thereby improving their adaptive capacity to energy vulnerability | Binary {1-Yes; 2-No} | 1 | 2 | 1.39 | 0.49 |
| Income from business | | | 1 | 2 | 1.87 | 0.33 |
| Remittances | | | 1 | 2 | 1.80 | 0.40 |
| Pensions | | | 1 | 2 | 1.95 | 0.23 |
| Grants | | | 1 | 2 | 1.42 | 0.50 |
| Sales from farming products and services | | | 1 | 2 | 1.98 | 0.13 |
| Other income | | | 1 | 2 | 1.98 | 0.15 |
| Main income sources | According to Robinson (2019), occupation can have a bearing on the vulnerability to energy poverty. | Nominal {1-Salaries/wage/commission; 2-Income from business; 3-Remittances; 4-Pensions; 5-Grant; 6-Sales from farming products and services; 7-Other income} | 1 | 7 | 2.60 | 1.85 |
| Income from remittances | Actual amount of income enables households to adapt to energy insecurity. High income improves the adaptive capacity. Robinson (2019) avers that low incomes entail marginalisation and less able to afford energy bills | Actual amount {R} | 0 | 20000 | 281.48 | 967.72 |
| Income from pensions | | | 0 | 50000 | 379.31 | 2367.45 |
| Net household income | | | 0 | 500000 | 9500.46 | 16364.83 |
| Own a motor vehicle | Assets that are easily liquidated can enable a household to adapt to instance of energy insecurity | Binary {1-Yes; 2-No} | 1 | 2 | 1.71 | 0.45 |
| Radio ownership | | Binary {1-Yes; 2-No} | 1 | 2 | 1.43 | 0.50 |
| Number of radios | | Actual number | 0 | 12 | 0.62 | 0.65 |
| Wealth status of household | Wealth status corelates with income status. Wealth enables households to adapt to energy insecurity. | Ordinal {1 = Wealthy; 2-Very comfortable; 3-Reasonably comfortable; 4-Just getting along; 5-Poor; 6-Very poor} | 1 | 6 | 3.99 | 0.98 |
| Total household income (from salary) | Actual amount of income enables households to adapt to energy insecurity. High income improves the adaptive capacity. Robinson (2019) avers that low incomes entail marginalisation and less able to afford energy bills | Actual amount (R) | 0 | 40000 | 7788.07 | 9977.13 |
| **Sensitivity – The sensitivity of a household to energy poverty** | | | | | | |
| Quality of electricity | Perceptive state of electricity supply highlights the sensitivity of the households to energy poverty | Ordinal {1-Good; 2-Average; 3-Poor} | 1 | 3 | 1.95 | 0.23 |
| Monthly income per month | Intermittent income makes households sensitive to energy insecurity. Robinson (2019) avers that low incomes entail marginalisation and less able to afford energy bills. Other authors also utilised | Actual amount (R) | 0 | 820000 | 7318.89 | 17067.18 |

(continued on next page)

Table 1 (*continued*)

| Variable | Justification | Measurement | Min $S_{min}$ | Max $S_{max}$ | Mean | Std. Dev. |
|---|---|---|---|---|---|---|
| | income for energy vulnerability assessments (Hill, 2011) | | | | | |
| Own a TV | Owning energy consuming assets can increase the sensitivity to energy poverty (Wang et al., 2015) | Binary {1-Yes; 2-No} | 1 | 2 | 1.12 | 0.33 |
| Own a DVD | | | 1 | 2 | 1.43 | 0.50 |
| Own a refrigerator | | | 1 | 2 | 1.18 | 0.38 |
| Own and electric stove | | | 1 | 2 | 1.07 | 0.26 |
| Household size | Large households tend to consume more energy thereby increasing the sensitivity to energy poverty. Robinson (2019) also used age as an indicator of vulnerability to energy insecurity | Actual number | 1 | 22 | 3.67 | 2.37 |
| Household monthly salary (relative to minimum income) | Intermittent income makes households sensitive to energy poverty. Robinson (2019) avers that low incomes entail marginalisation and less able to afford energy bills | Ordinal {1-Much higher; 2-Higher; 3-More or less the same; 4-Lower; 5-Much lower} | 1 | 5 | 3.39 | 1.01 |

For a household $k$, (where $k = 1 \dots K$ and $K$ denotes the population of households), impact evaluations separate the impact of female-headed household ($D_k = 1$) on a certain outcome $Y_k(D_k)$ (EVI) from male-headed household ($D_i = 0$), the counterfactual scenario. This is the difference between the vulnerability index of female-headed household $k$ and the counterfactual potential of male-headed households:

$$\varphi_k = Y_k(1) - Y_k(0)$$

The impact $\varphi_k$ cannot be observed, since a household-head is either male or female, but never both. The average population effect is then sought after, through estimating the average treatment effect of the treated (ATT):

$$\varphi_{ATT} = E[\varphi|D=1] = E[Y(1)|D=1] - E[Y(0)|D=1]$$

Since $E[Y(0)|D=1]$ is unobservable, the method subtracts the unobserved effect of the male-headed household group ($E[Y(0)|D=0]$) had they been female-headed households.

$$E[Y(1)|D=1] - E[Y(0)|D=0] = \varphi_{ATT} + E[Y(0)|D=1] - E[Y(0)|D=0]$$

The equations' right-hand side represents impact under investigation, with the two last terms on the right-hand side representing selection bias. Thus, identifying true impact, $\varphi_{ATT}$ can only be done if

$$\Pr(X) = \Pr(D=1|X)$$

The resulting PSM estimator for ATT can then be generalised as:

$$\varphi_{ATT}^{PSM} = E_{\Pr(X)|D=1}\{E[\mathrm{Y}(1)|D=1, \Pr(X)] - E[\mathrm{Y}(0)|D=0, \Pr(X)]$$

The same process was followed in ascertaining the impact of race/ethnicity such as Black/African female-headed households against Coloured, Indian/Asian and White female-headed households on energy vulnerability, respectively. The following logit model was used in the PSM to ascertain impact of gender and/or ethnicity on the energy vulnerability index.

$$\ln\left(\frac{P_{(y=1)}}{1 - P_{(y=1)}}\right) = \varnothing_0 + \sum_{i=1}^{n} \varnothing_i \chi_i$$

which can be presented as follows:

$$\ln\left(\frac{P_{(y=1)}}{1 - P_{(y=1)}}\right) = \varnothing_0 + \varnothing_1 \chi_{1i} + \varnothing_2 \chi_{2i} + \dots + \varnothing_n \chi_i$$

The explanatory variables utilised were the energy requirement for the households. The resultant model is that shown below:

$$\ln\left(\frac{P_{(y=1)}}{1 - P_{(y=1)}}\right) = \varnothing_0 + \varnothing_1 CE + \varnothing_2 LE + \varnothing_3 WHE + \varnothing_4 SHE + v_i$$

where $CE$, $LE$, $WHE$ and, $SHE$ represent the sources of cooking energy, lighting energy, water heating energy and space heating energy, respectively.

## 4. Results and discussion

### 4.1. Descriptive statistics: gender, ethnicity and energy use

Fig. 1 shows the gender distribution of the respondents. The gender disparities per race/ethnicity were increasing from Black/Africans, Coloured, Indian/Asian and White, respectively.

Table 3 indicates the female-headed household respondent distribution in the various Provinces of South Africa. Most Black/African female-headed households were from KwaZulu-Natal (18.1%), Eastern Cape (19.9%) and Gauteng (15.0%) Provinces, respectively, with the least from Northern Cape (22.3%). Most Coloured female-headed households were from Western Cape Province (52.3%), followed by Northern Cape Province (22.3%). KwaZulu-Natal (76.1%) held most of the Indian/Asian female-headed households, followed by Gauteng (34.8%), whilst Western Cape (34.8%) and Gauteng (30.7) Provinces had most White female-headed households. The high overall percentages of female-headed households noted for the Eastern Cape and KwaZulu-Natal Provinces can be attributed to labour migration, be it by males in the departure areas or female in the arrival areas (Nwosu and Catherine, 2018). Furthermore, socio-cultural changes that erode extended family structures, making single parenting more permissible has been accepted. However, female headship has been linked to increased poverty, hence the two provinces having the highest proportion of non-electrified households (DoE, 2012). Non-electrified households depend on traditional sources of energy such as firewood, where household labour rests on the shoulders of women. Spatial differences can have a bearing on energy poverty (Crentsil et al., 2019). Predominantly rural areas tend to have higher energy poverty compared to urban areas. This is through differentiated regional and demographic characteristics which affect attitudes towards energy security(Knox-Hayes et al., 2013). In South Africa, only 80% of the rural population is connected to electricity despite government efforts in the integrated national electricity programme and the free basic electricity policy (ANA, 2018). Most of the White female-headed households are located in urban areas for instance, and hence are likely to be more energy secure compared to Black/Africa female-headed households mostly from KwaZulu-Natal and Eastern Cape Provinces, and in the rural areas. Rural areas have higher likelihood of energy poverty due to locational differences on availability, reliability and accessibility of clean and modern fuels (Crentsil et al., 2019). Furthermore, Fatona et al. (2013) articulate that participation of rural women in energy has mainly been restricted to traditional energy sources compared to urban women. The World Elections (World Elections, 2014) noted that the Apartheid era caused the distribution by race/ethnicity in South Africa. The black population

**Table 2**
Sample size and location.

| Race | Western Cape | | Eastern Cape | | Northern Cape | | Free State | | KwaZulu- Natal | | North West | | Gauteng | | Mpumalanga | | Limpopo | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| **Black/African** | 302 | 199 | 795 | 955 | 199 | 181 | 389 | 394 | 848 | 961 | 495 | 402 | 1197 | 800 | 580 | 489 | 761 | 943 | **5566** | **5324** |
| **Coloured** | 401 | 267 | 96 | 60 | 160 | 114 | 27 | 16 | 14 | 6 | 9 | 8 | 50 | 36 | 3 | 0 | 3 | 4 | **763** | **511** |
| **Indian/Asian** | 5 | 0 | 5 | 1 | 2 | 0 | 1 | 1 | 125 | 54 | 4 | 0 | 45 | 14 | 5 | 0 | 9 | 1 | **201** | **71** |
| **White** | 221 | 92 | 50 | 15 | 28 | 12 | 49 | 20 | 62 | 17 | 55 | 19 | 253 | 81 | 50 | 7 | 24 | 1 | **792** | **264** |
| **Total** | **929** | **558** | **946** | **1031** | **389** | **307** | **466** | **431** | **1049** | **1038** | **563** | **429** | **1545** | **931** | **638** | **496** | **797** | **949** | **7322** | **6170** |

M – Male-headed household.
F – Female-headed household.

was separated into urban townships on ethnic groups and received their schooling based on their race. The same separation implied to coloured's and Indians as they were also altered to separate schools (SAHO, 2021). Therefore, Africans struggle to move away from those arrangements since most are underprivileged and from low-income households.

It should also be noted that the power plant distribution in the country can have a bearing in energy security. Fig. 2 shows that most of the coal-powered power stations in South Africa are located in Mpumalanga, Gauteng and Limpopo, providing 77% of the country total energy capacity. This is where most of the coal deposits are located, with these provinces also exhibiting the highest grid expansion (Hafner et al., 2019). Most renewable energy is found in the Cape Provinces with lower capacity and grid expansion.

Table 4 shows the energy sources for cooking, lighting, water heating and space heating for female-headed households in South Africa. Most of the energy sources in these various household activities emanate from electricity from mains. Worrying is the high usage of non-renewable coal energy for Black/African female-headed households for cooking (15.4%), water heating (11.9%) and space heating (15.3%). Clancy et al. (2003) highlight that cooking with electricity, for instance, is not cheap in terms of the energy itself or the stove used, especially for female-headed households, both rich and poor. There is also a higher usage of animal dung amongst the female-headed households in terms of cooking, water heating and space heating. Lack of access to modern energy sources is associated with energy poverty (Ozughalu and Ogwumike, 2019). In the energy ladder hypothesis, Hosier and Dowd (1987) postulate that as household socio-economic status improves, households tend to switch from traditional biomass fuels to sophisticated modern fuels. This is in line with the theory of transition (Ozughalu and Ogwumike, 2019). The free basic electricity policy in South Africa has tried to fast track the transition from biomass fuels. This was after the realisation that increased electrification would not automatically increase poor household electricity consumption. Makonese et al. (2018) however avers that this policy was a failure as the energy provided was not significant enough to meet basic energy needs. Contrary however, the fuel stacking model, which is more apparent in the current case, identifies that rather than switching from traditional to modern fuels, households build a portfolio of energy sources combining different fuels (Masera et al., 2000). Households partially switch as they adopt modern fuel types such as electricity, whilst still keeping traditional fuels such as coal (Crentsil et al., 2019). This is attributed to the increase in the chances of having energy supply or on various cultural and social factors, as well as taste and preferences (Ozughalu and Ogwumike, 2019). However, utilisation of traditional biomass fuels increases the mortality of women and children, and reduces opportunities to participate in other economic activities. Thus labour saving energy technologies utilising modern fuels reduces mortalities and frees up time spent by women on domestic activities on other productive ventures (Listo, 2018).

### 4.2. *Gender and ethnic differences in energy security for female-headed households in South Africa*

Table 5 shows the energy vulnerabilities for households in South Africa. The table shows that the highest exposure indicator for male-headed households was electricity being cut for non-payment followed by property ownership. For female-headed households, it is property ownership followed by electricity being cut for non-payment. Generally, the un-electrified households in South Africa originate from low-income households and therefore, cannot pay for electricity connections (Mgwambani et al., 2018). Pueyo and Maestre (2019) indicated that men and women have different roles to play in their societies, and different priorities for various energy services therefore their willingness to pay for electricity bills also differs. Generally, women do most household chores, since having electricity makes their lives easier (O'Dell et al., 2014); their willingness to pay for electricity bills is more

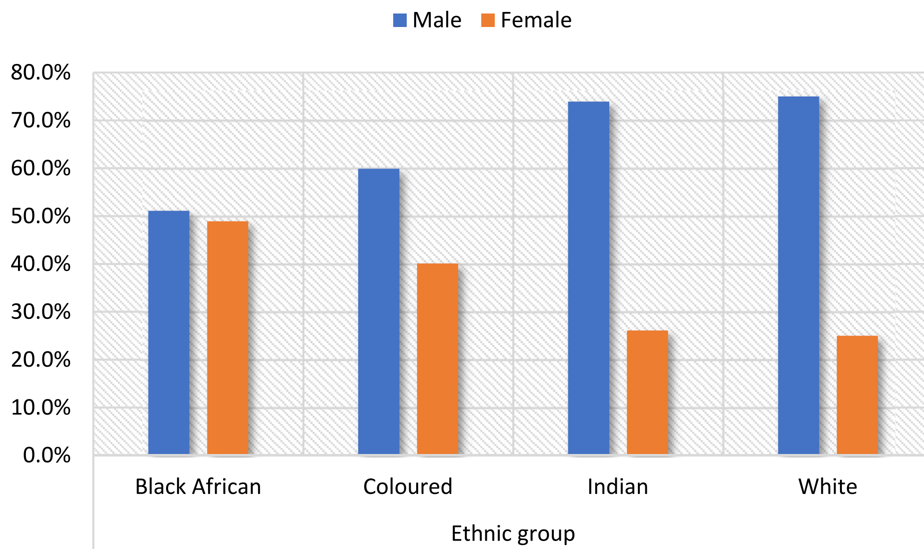


**Fig. 1.** Gender and ethnic distribution of the respondents in the study site.

**Table 3**
Location of female-headed households in the study (%).

| | Western Cape | Eastern Cape | Northern Cape | Free State | KwaZulu-Natal | North West | Gauteng | Mpumalanga | Limpopo |
|---|---|---|---|---|---|---|---|---|---|
| **Black/African** | 3.7 | 17.9 | 3.4 | 7.4 | 18.1 | 7.6 | 15.0 | 9.2 | 17.7 |
| **Coloured** | 52.3 | 11.7 | 22.3 | 3.1 | 1.2 | 1.6 | 7.0 | 0.0 | 0.8 |
| **Indian/Asian** | 0.0 | 1.4 | 0.0 | 1.4 | 76.1 | 0.0 | 19.7 | 0.0 | 1.4 |
| **White** | 34.8 | 5.7 | 4.5 | 7.6 | 6.4 | 7.2 | 30.7 | 2.7 | 0.4 |
| **Total** | 9.0 | 16.7 | 5.0 | 7.0 | 16.8 | 7.0 | 15.1 | 8.0 | 15.4 |

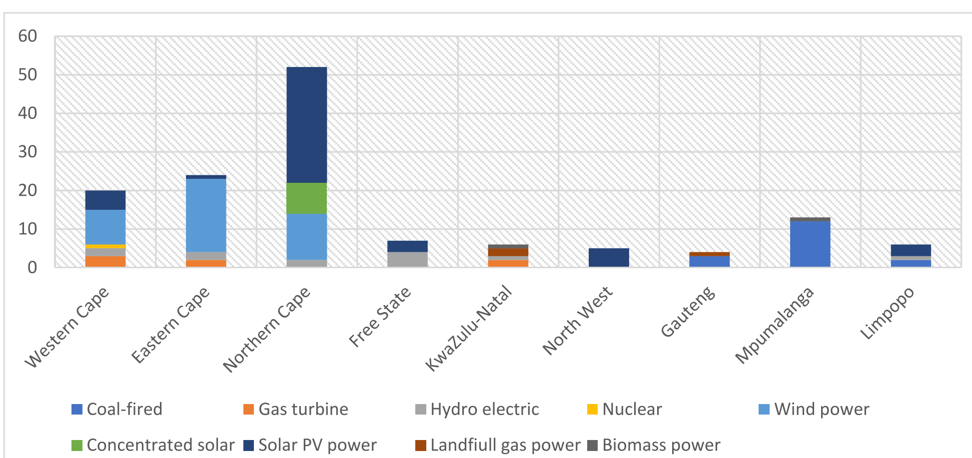


**Fig. 2.** Number of power stations and their provincial distribution in South Africa.

compared to men. There is evidence of high energy poverty in rural areas, peri-urban and informal settlements of South Africa (Makonese et al., 2016) due to high fuel prices and high electricity tariffs in recent years (Merten, 2019), indicating negative implications to the household's energy access. High tariffs will lead to electricity cuts due to unaffordability and inability to pay. Worth noting is the household expenditure, which more than doubles the exposure for female-headed households to energy vulnerability as compared to male-headed households. This scenario might be that male-headed household share resources to pay for electricity. In terms of race/ethnicity, the highest exposure is observed for Indian/Asian female-headed households when electricity is being cut for non-payment, as well as household expenditure, which is also a feature of White female-headed households. White and Indian/Asian female-headed households are characterised by high household expenditures due to their high living standards, exposing them to energy vulnerability, as there is high propensity to spend on energy. Black/African female-headed households are characterised by electricity complaints and property ownership. Lack of assets such as property and the effects of intermittent electricity supplies tends to expose Black/African female-headed households to energy poverty.

Table 5 further shows that male-headed households are better adapted to energy vulnerability because of the various income sources, followed by salaries and wages. Because of gendered norms, women's income is usually lower as compared to men (Winther et al., 2020). Continuing with these unfavourable norms to women will only cause them to have less power in the electricity distribution at the

**Table 4**
Energy used for cooking, lighting, water heating and space heating by female-headed households in South Africa.

| | None | Other sources | Gas | Paraffin | Wood | Coal | Candles | Animal dung | Solar energy | Electricity from mains |
|---|---|---|---|---|---|---|---|---|---|---|
| **Energy for cooking (%)** | | | | | | | | | | |
| **Black/African** | 0.1 | 0.2 | 0.2 | 0.0 | 0.7 | 15.4 | 1.0 | 1.5 | 0.2 | 80.7 |
| **Coloured** | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 1.2 | 0.4 | 5.9 | 0.2 | 92.2 |
| **Indian/Asian** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 0.0 | 95.8 |
| **White** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.7 | 0.4 | 90.9 |
| **Total** | 0.0 | 0.2 | 0.2 | 0.0 | 0.6 | 13.4 | 0.9 | 2.2 | 0.2 | 82.3 |
| **Energy for lighting (%)** | | | | | | | | | | |
| **Black/African** | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 | 99.4 |
| **Coloured** | 0.2 | 0.2 | 0.0 | 0.2 | 0.0 | 0.4 | 0.0 | 0.0 | 0.2 | 98.8 |
| **Indian/Asian** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100 |
| **White** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 99.6 |
| **Total** | 0.1 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 | 99.3 |
| **Energy for water heating (%)** | | | | | | | | | | |
| **Black/African** | 0.2 | 0.4 | 0.1 | 0.0 | 0.4 | 11.9 | 1.7 | 0.5 | 0.1 | 84.7 |
| **Coloured** | 2.2 | 0.2 | 0.0 | 0.0 | 0.0 | 1.0% | 0.0 | 1.4 | 0.2 | 95.1 |
| **Indian/Asian** | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4% | 0.0 | 1.4 | 0.0 | 95.8 |
| **White** | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0% | 0.0 | 2.3 | 0.4 | 96.6 |
| **Total** | 0.3 | 0.4 | 0.0 | 0.0 | 0.3 | 10.4% | 1.5 | 0.6 | 0.1 | 86.2 |
| **Energy for space heating (%)** | | | | | | | | | | |
| **Black/African** | 42.3 | 0.1 | 0.2 | 0.2 | 1.9 | 15.3 | 11.5 | 1.2 | 0.1 | 27.4 |
| **Coloured** | 55.2 | 0.2 | 0.0 | 0.0 | 0.2 | 6.1 | 1.4 | 1.2 | 0.0 | 35.8 |
| **Indian/Asian** | 42.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 0.0 | 1.4 | 1.4 | 53.5 |
| **White** | 34.8 | 1.1 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 9.5 | 0.4 | 51.5 |
| **Total** | 43.1 | 0.1 | 0.1 | 0.1 | 1.7 | 13.8 | 10.0 | 1.5 | 0.1 | 29.4 |

**Table 5**
Energy vulnerability indices for households in South Africa.

| Subcomponent | Indices | | | | | |
|---|---|---|---|---|---|---|
| | Male-headed households | Female-headed household | | | | |
| | | **Overall** | **Black/African** | **Coloured** | **Indian/Asian** | **White** |
| **Exposure** | | | | | | |
| Household age | 0.369 | 0.275 | 0.289 | 0.239 | 0.112 | 0.166 |
| Ownership of dwelling | 0.680 | 0.783 | 0.801 | 0.732 | 0.715 | 0.629 |
| Access to electricity | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Electricity complaints | 0.530 | 0.523 | 0.825 | 0.525 | 0.535 | 0.531 |
| Electricity cut for non-payment | 0.729 | 0.717 | 0.739 | 0.508 | 0.944 | 0.720 |
| Household expenditure | 0.250 | 0.651 | 0.626 | 0.751 | 0.839 | 0.902 |
| Domestic worker services | 0.120 | 0.060 | 0.194 | 0.050 | 0.270 | 0.460 |
| Total exposure | **0.519** | **0.501** | **0.502** | **0.475** | **0.552** | **0.552** |
| **Adaptive capacity** | | | | | | |
| Salary/wage/income | 0.680 | 0.520 | 0.490 | 0.710 | 0.680 | 0.570 |
| Income from business | 0.160 | 0.090 | 0.090 | 0.030 | 0.100 | 0.130 |
| Remittances | 0.130 | 0.280 | 0.290 | 0.180 | 0.250 | 0.180 |
| Pensions | 0.060 | 0.050 | 0.030 | 0.005 | 0.070 | 0.310 |
| Grants | 0.450 | 0.730 | 0.750 | 0.740 | 0.650 | 0.240 |
| Sales from farming products and services | 0.020 | 0.020 | 0.020 | 0.010 | 0.000 | 0.010 |
| Other income | 0.020 | 0.020 | 0.020 | 0.003 | 0.070 | 0.110 |
| Income sources | 0.876 | 0.798 | 0.789 | 0.847 | 0.872 | 0.857 |
| Income from remittances | 0.008 | 0.021 | 0.021 | 0.016 | 0.029 | 0.037 |
| Income from pensions | 0.010 | 0.005 | 0.002 | 0.006 | 0.002 | 0.054 |
| Net household income | 0.233 | 0.014 | 0.013 | 0.014 | 0.023 | 0.031 |
| Own a motor vehicle | 0.400 | 0.160 | 0.110 | 0.230 | 0.550 | 0.880 |
| Radio ownership | 0.590 | 0.540 | 0.530 | 0.520 | 0.770 | 0.740 |
| Number of radios | 0.055 | 0.483 | 0.046 | 0.048 | 0.081 | 0.072 |
| Wealth status of household | 0.421 | 0.378 | 0.366 | 0.390 | 0.431 | 0.560 |
| Total household income | 0.245 | 0.135 | 0.116 | 0.170 | 0.252 | 0.410 |
| Total adaptive capacity | **0.260** | **0.238** | **0.230** | **0.249** | **0.302** | **0.324** |
| **Sensitivity** | | | | | | |
| Quality of electricity | 0.822 | 0.828 | 0.825 | 0.833 | 0.782 | 0.882 |
| Monthly income per month | 0.423 | 0.377 | 0.365 | 0.398 | 0.472 | 0.530 |
| Own a TV | 0.880 | 0.870 | 0.860 | 0.920 | 0.970 | 0.970 |
| Own a DVD | 0.600 | 0.520 | 0.510 | 0.560 | 0.790 | 0.670 |
| Own a refrigerator | 0.820 | 0.820 | 0.800 | 0.880 | 0.970 | 0.990 |
| Own and electric stove | 0.940 | 0.920 | 0.910 | 0.970 | 0.990 | 0.990 |
| Household size | 0.117 | 0.139 | 0.143 | 0.147 | 0.082 | 0.046 |
| Household monthly salary | 0.012 | 0.005 | 0.004 | 0.006 | 0.011 | 0.018 |
| Total sensitivity | **0.577** | **0.560** | **0.552** | **0.589** | **0.633** | **0.637** |
| **Energy vulnerability index** | **0.149** | **0.147** | **0.150** | **0.133** | **0.158** | **0.145** |

intra-household (Nathan et al., 2018). Female-headed households are better adapted to energy vulnerability through varied income sources followed by accessing grants. Comparing different races/ethnic groups, White female-headed households were better adapted due to ownership of vehicles, which can be liquidated when required. This is followed by the various income sources, which appear as an essential adaptive capacity across all races/ethnic groups. Indian/Asian female-headed households are better adapted through radio asset ownership, whilst Black/African, Coloured and Indian/Asian female-headed households rely on grants to adapt to energy poverty.

Across the board, Table 5 shows that there is high sensitivity to energy poverty for energy utilising assets such as electric stove, refrigerator and television. In rural and urban areas, electricity is the best option for cooking in South Africa (IEA, 2019). However, more than 4 million people in rural areas prefer using fuelwood for cooking and heating households, which is expected to persist in 2030 (IEA, 2019). Historic racial and employment discrimination, poor school systems that limit economic opportunity and difficulty getting credit are also factors contributing to energy poverty among the Blacks and Coloureds in South Africa.

Table 6 shows that there are significant mean differences in the exposure, adaptive capacity and sensitivity to energy poverty between male and female-headed households at the 1% level. However, there was no significant difference in the overall EVI. Table 6 also shows that male-headed households had more exposure (3.47%), adaptive capacity (8.46%) and sensitivity (2.94%) to energy poverty. The results indicate that women are less exposed and sensitive to energy poverty; however, women have the lowest adaptive capacity than men. This could be explained by the fact that women are responsible for the household's energy requirement, such as cooking, boiling water, and appliances, and therefore are always willing to meet their energy needs by paying electricity bills and fetching wood. In some communities, men are more likely to be exposed to energy poverty because of norms and cultural beliefs (Winther et al., 2020). For instance, in some communities fetching wood is considered women's work (Tchereni et al., 2013). Therefore, women are the only ones collecting wood, making then more energy secure compared to men. Men and women have different roles, needs and aspirations for energy (Fatona et al., 2013). Children and women are often the primary users of household energy and often affected by lack of access to clean, affordable and sustainable energy. According to Healy and Clinch (2002), single parent households, lone pensioner households, widowed, separated or divorced exhibited high levels of energy poverty. Kearns et al. (2019) support this, highlighting that single parents have a propensity to move into fuel poverty which is reflective of their single source of low income. In a study in Ghana, Crentsil et al. (2019) found that female-headed households were more deprived of energy compared to male-headed households. These were similar findings by Ozughalu and Ogwumike (2019) in Nigeria and Karpinska and Śmiech (2020) in Poland. However, Listo (2018) asserts that gendered patterns of fuel collection varies across geographical and cultural contexts. This is often based on household labour decisions and contextual social norms. In addition, Clancy et al. (2003) highlighted that even in households were both men and women are present, based on gendered division of labour, it is still the women's responsibility to provide energy in their spheres of influence, mainly the kitchen. Men tend to view energy in terms of leisure and quality of life, whilst women view it as means of reducing their workload, improving health and reducing expenditure (Clancy et al., 2003).

Table 7 shows the energy security differences for different races/ethnicities of female-headed households in South Africa. It is shown that Black/African female-headed households had a 5.34% more exposure to energy poverty compared to Coloured female-headed households. However, there was a 9.96% less exposure to energy poverty for Black/African female-headed households compared to both Indian/Asian and White female-headed households, respectively. Furthermore, Coloured, Indian/Asian and White female-headed households had 9.36%, 31.30% and 40.87% more adaptive capacity to energy poverty compared to Black/African female-headed households. Black/African female-headed households were also 6.7%, 14.67% and 15.40% less sensitive to energy poverty compared to Coloured, Indian/Asian and White female-headed households, respectively. Overall, Black/African female-headed households were 11.33% more vulnerable to energy poverty compared to Coloured female-headed households. They were also 3.33% more vulnerable to energy poverty compared to White female-headed households. However, Indian/Asian female-headed households were 5.33% more vulnerable to energy poverty compared to Black/African female-headed households. A study by Churchill and Smyth (2020) found similar results of ethnicity having an association with energy poverty in Australia. The findings might be linked to income and ethnicity disparities as Whites in South Africa earn about eight times more per capita than Blacks/Africans, Indians and Coloureds (Mpeta et al., 2018). Gradin (2013) attests that the income disparities are mostly driven by inequalities in access to the labour market, education, location, and family planning institutes. This could emanate from the historical perspective, feeding into the welfare and livelihoods, as well as living standards of the various races/ethnicities. According to Belaïd (2018), energy poverty is more pronounced on foreign families living in multi-dwelling buildings. Unemployment also tends to increase vulnerability to energy poverty. This can be exacerbated by increased household sizes (Scarpellini et al., 2015). In view of the theory of transition (Ozughalu and Ogwumike, 2019), which implies that underdevelopment is associated with energy poverty, where it decreases as development increases, this has been evident in Black/African communities compared to White, Indian/Asian and Coloured communities in South Africa.

### 4.3. *Impact of gender and ethnicity on energy security for female-headed households in South Africa*

Table 8 shows the Propensity Score Matching results comparing male and female-headed households. The table confirms that for households with similar energy utilisation in terms of cooking, lighting, water and space heating, male-headed households had significantly more exposure, adaptive capacity ($P < 0.01$) and sensitivity ($P < 0.05$) compared to female-headed households. Overall, however, there was no significant difference on the energy poverty, even though female-headed households had a higher EVI. A study by Núñez-Peiró et al. (2021) in Madrid indicated that it is women of an older age living alone that are at the

**Table 6**
Energy security differences for male and female-headed households in South Africa.

| | Gender | | | | Mean difference | % Mean difference |
|---|---|---|---|---|---|---|
| | Men | | Women | | | |
| | Mean | Standard deviation | Mean | Standard deviation | | |
| **Exposure** | 0.519 | 0.097 | 0.501 | 0.090 | 0.018(0.000) | 3.47 |
| **Adaptive capacity** | 0.260 | 0.084 | 0.238 | 0.077 | 0.022(0.000) | 8.46 |
| **Sensitivity** | 0.577 | 0.115 | 0.560 | 0.111 | 0.017(0.000) | 2.94 |
| **Energy vulnerability index** | 0.149 | 0.06 | 0.147 | 0.069 | 0.002(0.167) | 1.34 |

Sig value in parenthesis.

**Table 7**
Energy security differences for different ethnicities for female-headed households in South Africa.

| | Exposure | | Adaptive capacity | | Sensitivity | | Energy vulnerability index | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. dev | Mean | Std. dev | Mean | Std. dev | Mean | Std. dev |
| **Black/African** | 0.502 | 0.087 | 0.230 | 0.074 | 0.552 | 0.109 | 0.150 | 0.065 |
| **Coloured** | 0.475 | 0.095 | 0.249 | 0.074 | 0.589 | 0.097 | 0.133 | 0.074 |
| ***t*** | 7.299 | | −6.254 | | −5.483 | | 8.308 | |
| **Mean difference** | 0.027(0.000) | | −0.019(0.000) | | −0.037(0.000) | | 0.017(0.000) | |
| **% Mean difference** | 5.34 | | −9.36 | | −6.7 | | 11.33 | |
| **Indian/Asian** | 0.552 | 0.093 | 0.302 | 0.075 | 0.633 | 0.829 | 0.158 | 0.073 |
| ***t*** | −4.856 | | −7.999 | | −5.253 | | −0.812 | |
| **Mean difference** | −0.05(0.000) | | −0.072(0.000) | | −0.081(0.000) | | −0.008(0.323) | |
| **% Mean difference** | −9.96 | | −31.30 | | −14.67 | | −5.33 | |
| **White** | 0.552 | 0.112 | 0.324 | 0.065 | 0.637 | 0.068 | 0.145 | 0.086 |
| ***t*** | −7.802 | | −20.604 | | −11.133 | | 3.256 | |
| **Mean difference** | −0.05(0.000) | | −0.094(0.000) | | −0.085(0.000) | | 0.005(0.068) | |
| **% Mean difference** | −9.96 | | −40.87 | | −15.40 | | 3.33 | |

Sig value in parenthesis.

**Table 8**
Average Treatment Effects of female-headed household's vs male-headed households in energy security.

| | Coefficient | z | $P > \|z\|$ |
|---|---|---|---|
| **Exposure** | −0.013 | −7.84 | 0.000 |
| **Adaptive capacity** | −0.016 | −11.36 | 0.000 |
| **Sensitivity** | −0.004 | −2.53 | 0.039 |
| **Energy vulnerability index** | 0.001 | 1.06 | 0.301 |

highest risk on energy vulnerability. Their study was however not exhaustive on the measures of vulnerability choosing to concentrate on household head as a measure of vulnerability. Female-headed households are the poorest, experiencing more poverty than male-headed households. This has been due to labour migration, marital breakdown under financial stress and lack of formal marriage. Headship reinforces poverty as women are time and resource-constrained by their reproductive, productive and community engagement roles and face labour market discrimination (Munien and Ahmed, 2012).

Table 9 shows the Average Treatment Effects for the Treated (ATT) for energy poverty for female-headed households in South Africa. It shows that Black/African female-headed households had less exposure and energy poverty as compared to Coloured female-headed households. However, Coloured female-headed households were better adapted to energy poverty. Table 9 further shows that compared to Indian/Asian and White, Black/African female-headed households had more exposure, adaptive capacity and sensitivity to energy poverty. Crentsil et al. (2019) attribute differences in energy poverty based on the urban-rural divide. A large portion of Black-African female-headed households are located in rural areas, where they are characterised with high energy poverty compared to Indian/Asian and White female-headed households. Ismail and Khembo (2016) study indicated that the Northern Cape and the Eastern Cape Provinces experienced the highest energy poverty, hence vulnerable. Most of the populace in the afore mentioned provinces are characterised by low-income and cannot pay for electricity connection bills. Provinces with lower energy poverty are mostly urbanised and this could mean that inhabitants have more access to cleaner energy source (Odeku and Meyer, 2019). Furthermore, energy poverty increases for older aged persons (Crentsil et al., 2019). In South Africa, the older Black/Africans are located in rural areas, thus creating more energy vulnerability for female-headed households in those areas. In addition, the older aged tend to utilise more traditional energy sources. Low educational levels also exacerbate energy poverty. Black/African women tend to be less educated than White and Indian/Asian women thereby increasing their vulnerability to energy poverty. The results of this study also concur with Kohler et al. (2009) who observed that differences of poverty between races can be explained by unequal access to education, family planning, and high unemployment or by the fact that they live in more deprived undeveloped areas. Each of these factors are likely to affect the income of an individual and contribute towards higher energy poverty.

Table 10 shows that there were significant differences in cooking (1%), lighting (5%) and water heating (1%) energy sources between male and female-headed households. Households are likely to increase electrical energy use in cooking and water heating if the household head is female, whilst it will increase lighting energy use if it is male-headed. Generally, in female-headed households, females do most of the cooking compared to men. This is because of limited working time since most women are unemployed or raising children at home. Therefore, many women tend to allocate their time in cooking. Table 10 also shows that Coloured female-headed households are likely to use more electrical energy in lighting and space heating compared to Black/African women. Half of the Coloured female-headed households from the sample were located in Western Cape Province, which is characterised by colder winters as compared to the other parts of South Africa. The amount of heating tends to depend on climate, weather, physical state and wellness of the household members (Day et al., 2016). According to Castaño-rosa et al. (2019a) not only has energy poverty been associated with long winters for space heating, this has also been a feature with hot summers for space cooling. This could explain the augmented space-heating energy use compared to Black/Africa female-headed households. In comparison to Coloureds, Black/African female-headed households will use

**Table 9**
Average Treatment Effects of Black/Africans vs White, Coloured and Indian/Asian female-headed households in energy security.

| | Coloured | | | Indian/Asian[a] | | | White | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Coefficient** | **z** | $P > \|z\|$ | **Coefficient** | **z** | $P > \|z\|$ | **Coefficient** | **z** | $P > \|z\|$ |
| **Exposure** | −0.026 | −2.46 | 0.014 | 0.052 | 2.37 | 0.018 | 0.071 | 6.73 | 0.000 |
| **Adaptive capacity** | 0.009 | 1.90 | 0.057 | 0.058 | 2.70 | 0.007 | 0.095 | 13.27 | 0.000 |
| **Sensitivity** | −0.014 | −1.07 | 0.228 | 0.049 | 4.80 | 0.000 | 0.063 | 9.90 | 0.000 |
| **Energy vulnerability index** | −0.023 | −3.80 | 0.000 | 0.010 | 0.62 | 0.520 | 0.004 | 0.48 | 0.701 |

[a] Lighting use was eliminated from the analysis as there was no differential use, thus non-comparability.

**Table 10**
Probit results for gender and race/ethnic differences in energy use.

| | Men vs women | | Black/African women vs Coloured women | | Black/African women vs Indian/Asian women[a] | | Black/African women vs White women | |
|---|---|---|---|---|---|---|---|---|
| | $\beta$ | z | $\beta$ | z | $\beta$ | z | $\beta$ | z |
| **Cooking** | 0.080 | 8.42(0.000) | −0.189 | −7.06(0.000) | −0.216 | −2.83(0.005) | −0.122 | −3.34(0.001) |
| **Lighting** | −0.052 | −2.07(0.038) | 0.127 | 2.79(0.005) | – | – | −0.119 | −0.56(0.573) |
| **Water heating** | 0.012 | 1.35(0.177) | −0.011 | −0.52(0.602) | 0.001 | 0.02(0.981) | −0.106 | −2.71(0.007) |
| **Space heating** | 0.014 | 5.72(0.000) | 0.015 | 2.91(0.004) | −0.017 | −1.59(0.112) | −0.024 | −4.95(0.000) |
| **constant** | −0.279 | −8.52(0.000) | −1.314 | 19.29(0.004) | −1.832 | −16.41(0.000) | −1.062 | −4.80(0.000) |
| $p$ | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| $R^2$ | | 0.0087 | | 0.0287 | | 0.0290 | | 0.0395 |

Sig value in parenthesis.
[a] Lighting use was eliminated from the analysis as there was no differential use, thus non-comparability.

more electrical energy in cooking and water heating. Black/African women-headed households also utilise more electrical energy in cooking and space heating, compared to Indian/Asian women-headed households, who tend to use more electrical energy on water heating. In comparison to White female-headed households, Black/African female-headed households use more electrical energy in cooking, lighting, water heating and space heating. Depending on culture, tradition and shared conventions, there are various demands for hot water for instance. Where some cultures and customs advocate for taking warm baths once a week, others stigmatise not taking it daily (Day et al., 2016). In South Africa, Chikulo (2014) indicated that in black communities, especially in rural areas, women are responsible for collecting wood and other biomass, and providing services such as cooking, cleaning, space heating and water heating.

The nearest neighbour matching in Table 11 shows that female-headed households were less exposed to energy poverty compared to male-headed households. Furthermore, the female-headed households exhibited less adaptive capacity and sensitivity to energy poverty compared to male-headed households. Overall, female-headed households were more vulnerable to energy poverty compared to male-headed households. This supports Crentsil et al. (2019), who indicated that female-headed households do not adopt modern energies due to cost barriers, thereby compromising their energy security. Furthermore, they were deprived of assets, increasing their likelihood to be energy poor. Table 11 also shows that Coloured female-headed households were less exposed to energy poverty. They had a higher adaptive capacity and sensitivity, but a lower vulnerability to energy poverty than Black/African female-headed households. Table 11 further shows that Indian/Asian and White female-headed households had more exposure, adaptive capacity and sensitivity to energy poverty compared to Black/African women. Both Indian/Asian and White female-headed households exhibited lower vulnerability to energy poverty.

## 5. Conclusion and policy implications

Gendered energy approaches have focussed on technical solutions, neglecting the immediate needs of women. These approaches have also neglected culture, socio-economic, political influences and race/ethnic disparities addressing gender differences. When it comes to energy, men and women play different production and consumption roles. Ignoring gender and ethnic divide in the energy sector is more or less one of the factors hindering the achievement of the SDGs. The study sought to ascertain female-headed households differentiated energy poverty based on the race/ethnic divide, taking South Africa as a case. As a result, the paper concludes that male-headed households are more exposed to electricity cuts due to non-payment, followed by property ownership. In contrast, women-headed homes are primarily exposed to energy poverty due to lack of property ownership assets. Male-headed households are better adapted to energy vulnerability because of various income sources, followed by salaries and wages, while women-headed households are better adapted to energy vulnerability through varied income sources and grants.

There is high utilisation of modern electrical energy amongst the female-headed households, indicating the likelihood of escaping energy poverty, as modern energy sources reduce burden on accessing energy. Female-headed households tend to increase utilisation of electricity in cooking and water heating compared to male-headed households. In comparison to Black/African, Coloured female-headed households tend to utilise more electrical energy in lighting and space heating, with Indian/Asian female-headed households utilise more electrical energy in water heating. Black/African female-headed households utilise more electrical energy in cooking, lighting, water heating and space heating compared to White female-headed households. Female-headed households exhibited less exposure, adaptive capacity and sensitivity to energy poverty compared to male-headed households. However, female-headed households exhibited more vulnerability to energy poverty compared to male-headed households. Black/African female-headed households were more exposed and had lower vulnerability relative to Coloured female-headed households, who were better adapted and had more sensitivity to energy poverty. Furthermore, Black/African female-headed households had less exposure, adaptive capacity and sensitivity to energy poverty compared to Indian/Asian and White female-headed households, respectively. However, Black/African female-headed households were more vulnerable to energy poverty compared to Indian/Asian and White female-headed households, respectively. This highlights stark inequality between the different races/ethnicities. Discourse on social equity, where gender is central, will be vital in providing the contextual knowledge necessary to move towards a future

**Table 11**
Nearest neighbour matching for gender and race/ethnic differences.

| | Men vs women | | Black/African women vs Coloured women | | Black/African women vs Indian/Asian women | | Black/African women vs White women | |
|---|---|---|---|---|---|---|---|---|
| | ATT | t | ATT | t | ATT | t | ATT | t |
| **Exposure** | −0.012 | −7.094 | −0.033 | −7.435 | 0.041 | 3.687 | 0.039 | 5.469 |
| **Adaptive capacity** | −0.015 | −10.253 | 0.014 | 3.845 | 0.061 | 6.669 | 0.077 | 17.132 |
| **Sensitivity** | −0.003 | −1.400 | 0.013 | 2.700 | 0.039 | 4.445 | 0.038 | 7.888 |
| **Energy vulnerability index** | 0.002 | 1.250 | −0.028 | −7.875 | −0.001 | −0.096 | −0.014 | −2.745 |

that builds on gendered energy security strategies that are suitable to the community.

Energy-related solutions go beyond just focusing on technical solutions and concentrate on providing alternative energy sources. More effort is therefore needed on identifying the relevance of gender and ethnicity concerning energy. In the long term, there is a greater need for scholars, policy makers and practitioners to prioritise the inclusion of gender and race/ethnic divide in energy policy. Based on the gender and race/ethnic disparities, there is a need for priority policy targeting if equitable energy security is to be achieved in South Africa. In the short term, the paper recommends that to improve adaptability to women's energy vulnerability, policymakers need to consider factors such as the availability of various income sources for different genders when compiling energy policies. Clean/renewable energy programmes should also address gender-ethnic disparities on energy through further research on cost-effectiveness of small-scale renewable energy projects. This should be accompanied by an education programme around renewable energy options to poorer and ethnic minority households, so that households do not view alternative energy sources as being inferior to electricity. Scaling up for this group has expediency of alleviating their energy poverty. Current energy policies, such as the Free Basic Electricity must be revised, such that it contributes towards more intensive energy poverty eradication. Economic opportunities for low-income female-headed households need to be addressed to improve access to green jobs and grow the green economy, thereby reducing vulnerability to energy poverty. There is need to improve educational opportunities for vulnerable females and provide better childcare opportunities. To augment the study, there is need to scrutinise the energy vulnerability of households across time obtainable from the various GHS since 2002. This can show the progression of gender based ethnic disparities in energy vulnerabilities over time.

## Data set

Data used in the study was obtained from DataFirst (StatsSA (2020). General Household Survey 2016. Statistics South Africa. Pretoria, South Africa https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/621/get-microdata).

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## CRediT authorship contribution statement

**Saul Ngarava:** Conceptualization, Formal analysis, Methodology, Writing – original draft. **Leocadia Zhou:** Project administration, Data curation. **Thulani Ningi:** Data curation. **Martin M. Chari:** Data curation. **Lwandiso Mdiya:** Methodology, Writing – original draft.

## 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.

## References

AGRA, 2018. Africa Agriculture Status Report 2018. Nairobi, Kenya.
Ahmad, L., Bhat, M.Y., Singh, V., 2021. Assessment of energy vulnerability in urban crowded space of Indian Himalaya. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-021-15408-x.
ANA, 2018. Eskom Expresses Pride on Improved Access to Electricity [WWW Document]. IOL. URL, 9.25.20. https://www.iol.co.za/news/south-africa/eskom-expresses-pride-on-improved-access-to-electricity-17259230.
Belaïd, F., 2018. Exposure and risk to fuel poverty in France: examining the extent of the fuel precariousness and its salient determinants. Energy Pol. 114, 189–200.
Bouzarovski, S., Thomson, H., Cornelis, M., 2021. Confronting energy poverty in europe: a research and policy agenda. Energies 14, 1–19. https://doi.org/10.3390/en14040858.
Brown, B., Spiegel, S.J., 2019. Coal, climate justice, and the cultural politics of energy transition. Global Environ. Polit. 19, 149–168. https://doi.org/10.1162/glep_a_00501.
Cannon, C.E.B., Chu, E.K., 2021. Gender, sexuality, and feminist critiques in energy research: a review and call for transversal thinking. Energy Res. Soc. Sci. 75, 102005. https://doi.org/10.1016/j.erss.2021.102005.
Carrim, M.N.H., Nkomo, S.M., 2016. Wedding Intersectionality Theory and identity work in organizations: South African Indian women negotiating managerial identity. Gend. Work. Organ. 23, 261–277. https://doi.org/10.1111/gwao.12121.
Castaño-rosa, R., Sherriff, G., Thomson, H., Solís, J., Marrero, M., 2019a. Transferring the index of vulnerable homes : application at the local-scale in England to assess fuel poverty vulnerability. Energy Build. 203 https://doi.org/10.1016/j.enbuild.2019.109458.
Castaño-rosa, R., Solís-guzmán, J., Rubio-bellido, C., Marrero, M., 2019b. Towards a multiple-indicator approach to energy poverty in the European Union : a review. Energy Build. 193, 36–48. https://doi.org/10.1016/j.enbuild.2019.03.039.
Chikulo, B.C., 2014. Gender, climate change and energy in South Africa : a review. Gend. Behav. 12, 5957–5970.
Churchill, S.A., 2017. Microfinance and ethnic diversity. Econ. Rec. 93, 112–141. https://doi.org/10.1111/1475-4932.12310.
Churchill, S.A., Elkins, M., Feeny, S., 2020. Ethnic diversity and progress towards the millennium development goals. In: Moving from the Millennium to the Sustainable Development Goals: Lessons and Recommendations. Palgrave Macmillan, pp. 155–180. https://doi.org/10.1007/978-981-15-1556-9_8.
Churchill, S.A., Nuhu, A.S., Lopez, K., 2019. Persistence of gender inequality: the role of ethnic divisions. Appl. Econ. 51, 781–796. https://doi.org/10.1080/00036846.2018.1513635.
Churchill, S.A., Smyth, R., 2020. Ethnic diversity, energy poverty and the mediating role of trust: evidence from household panel data for Australia1. Energy Econ. 86, 104663. https://doi.org/10.1016/j.eneco.2020.104663.
Clancy, J.S., Skutsch, M., Batchelor, S., 2003. The Gender - Energy- Poverty Nexus: Finding the Energy to Address Gender Concerns in Development. UK.
Cole, S.M., Puskur, R., Rajaratnam, S., Zulu, F., 2015. Exploring the intricte relationship between poverty, gender inequality and rural masculinity: a case study from an aqautic agricultural system in Zambia. Cult. Soc. Masculinities 7, 154–170. https://doi.org/10.3149/CSM.0702.154.
Crentsil, A.O., Asuman, D., Fenny, A.P., 2019. Assessing the determinants and drivers of multidimensional energy poverty in Ghana. Energy Pol. 133, 110884. https://doi.org/10.1016/j.enpol.2019.110884.
DAC, 2012. A National Strategy for Developing an Inclusive and Cohesive South African Society. Cape Town, South Africa.
David, A., Guilbert, N., Leibbrandt, M., Potgieter, E., Hino, H., 2018. Social Cohesion and Inequality in South Africa (No. Working Paper Series No. 219), Version 1. Institute for Justice and Reconciliation (IJR), Cape Town, South Africa.
Day, R., Walker, G., Simcock, N., 2016. Conceptualising energy use and energy poverty using a capabilities framework. Energy Pol. 93, 255–264. https://doi.org/10.1016/j.enpol.2016.03.019.
Dhamoon, R.K., 2011. Considerations on mainstreaming intersectionality. Polit. Res. Q. 64, 230–243.
DoE, 2012. A Survey of Energy-related Behaviour and Perceptions in South Africa: the Residential Sector 2012 [WWW Document]. Dep. Energy. URL, 10.1.20. http://www.energy.gov.za/files/media/Pub/DoE-2013-Survey-of-EnergyRelated-Behaviour-and-Perception-in-SA.pdf.
DoP, 2012. National Development Plan 2030. Our Future – Make it Work (Pretoria, South Africa).
Fatona, P., Abiodun, A., Olumide, A., Adeola, A., Abiodun, O., 2013. Viewing energy, poverty nd sustainability in Developing Countries through gender lens. In: New Developments in Renewable Energy, pp. 83–98. https://doi.org/10.5772/51818.
Feenstra, M., Özerol, G., 2021. Energy justice as a search light for gender-energy nexus: towards a conceptual framework. Renew. Sustain. Energy Rev. 138 https://doi.org/10.1016/j.rser.2020.110668.
Fisher, M., 2013. A Revealing Map of the World's Most and Least Ethnically Diverse Countries. Washington Post.
Genys, D., 2016. Towards sustainable development: tackling relations between energy security and social cohesion. J. Secur. Sustain. issues 6, 27–36.
Gradin, C., 2013. Poverty and deprivation in South Africa. J. Afr. Econ. 22, 187–238.
Graff, M., Carley, S., Konisky, D.M., Memmott, T., 2021. Which households are energy insecure? An empirical analysis of race, housing conditions, and energy burdens in the United States. Energy Res. Soc. Sci. 79, 102144. https://doi.org/10.1016/j.erss.2021.102144.
Habersbrunner, K., Martschew, E.-C., Rühlemann, A., Stock, A., 2020. Report on Gender Aspects of Existing Financial Schemes for Energy Poverty Measures (Germany).
Hafner, M., Tagliapietra, S., Falchetta, G., Occhiali, G., 2019. Country-level analysis: power sector, energy resources, and policy context. In: Renewables for Energy Access and Sustainable Development in East Africa. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-11735-1.
Hanger, S., Komendantova, N., Schinke, B., Zejli, D., Ihlal, A., Patt, A., 2016. Community acceptance of large-scale solar energy installations in developing countries: evidence from Morocco. Energy Res. Soc. Sci. 14, 80–89. https://doi.org/10.1016/j.erss.2016.01.010.
Healy, J.D., Clinch, J.P., 2002. Fuel poverty in Europe: a cross country analysis using a new composite measurement. In: Environmental Studies Research Series Working Papers.

Hill, J., 2011. Fuel poverty: The problem and its measurement. CASE Rep.. No. 69, London, UK.
Hosier, R.H., Dowd, J., 1987. Household fuel choice in Zimbabwe: an empirical test of the energy ladder hypothesis. Energy Resour. 9, 347–361.
IEA, 2019. Africa Energy Outlook 2019. Paris.
Ismail, Z., Khembo, P., 2016. Determinants of energy poverty in South Africa. J. Energy South Africa 26, 66–78.
Johnson, O.W., Han, J.Y.C., Knight, A.L., Mortensen, S., Aung, M.T., Boyland, M., Resurrección, B.P., 2020. Intersectionality and energy transitions: a review of gender, social equity and low-carbon energy. Energy Res. Soc. Sci. 70, 101774. https://doi.org/10.1016/j.erss.2020.101774.
Kabeer, N., 2015. Gender, poverty and inequality: a brief history of feminist contributions in the field of international development. Gend. Dev. 23, 189–205. https://doi.org/10.1080/13552074.2015.1062300.
Karpinska, L., Śmiech, S., 2020. Conceptualising housing costs: the hidden face of energy poverty in Poland. Energy Pol. 147 https://doi.org/10.1016/j.enpol.2020.111819.
Kearns, A., Whitley, E., Curl, A., 2019. Occupant behaviour as a fourth driver of fuel poverty ( aka warmth & energy deprivation ). Energy Pol. 129, 1143–1155. https://doi.org/10.1016/j.enpol.2019.03.023.
Khundi-Mkomba, F., Saha, A.K., Wali, U.G., 2021. Sociodemographic disparities in energy insecurity among low-income households before and during the COVID-19 pandemic. Int. J. Renew. Energy Dev. 10, 105–118. https://doi.org/10.14710/ijred.2021.33234.
Knox-Hayes, J., Brown, M.A., Sovacool, B.K., Wang, Y., 2013. Understanding attitudes toward energy security: results of a cross-national survey. Global Environ. Change 23, 609–622. https://doi.org/10.1016/j.gloenvcha.2013.02.003.
Kohler, M., Rhodes, B., Vermaak, C., 2009. Developing an energy-based poverty line for South Africa. J. Interdiscipl. Econ. 21, 163–195.
Koulouri, A., Mouraviev, N., 2019. Energy security through the lens of renewable energy sources and resource efficiency. In: Energy Security. Springer International Publishing, pp. 9–35. https://doi.org/10.1007/978-3-030-01033-1_2.
Łapniewska, Z., 2019. Energy, equality and sustainability? European electricity cooperatives from a gender perspective. Energy Res. Soc. Sci. 57 https://doi.org/10.1016/j.erss.2019.101247.
Lau, J.D., Scales, I.R., 2016. Identity, subjectivity and natural resource use: how ethnicity, gender and class intersect to influence mangrove oyster harvesting in the Gambia. Geoforum 69, 136–146. https://doi.org/10.1016/j.geoforum.2016.01.002.
Lieu, J., Sorman, A.H., Johnson, O.W., Virla, L.D., Resurrección, B.P., 2020. Three sides to every story: gender perspectives in energy transition pathways in Canada, Kenya and Spain. Energy Res. Soc. Sci. 68, 101550. https://doi.org/10.1016/j.erss.2020.101550.
Listo, R., 2018. Gender myths in energy poverty literature : a Critical Discourse Analysis. Energy Res. Soc. Sci. 38, 9–18. https://doi.org/10.1016/j.erss.2018.01.010.
Longe, O.M., 2020. A Review of Energy and Gender Poverty Nexus in South Africa. 2020. IEEE PES/IAS PowerAfrica. https://doi.org/10.1109/PowerAfrica49420.2020.9219885. PowerAfrica 2020.
Makonese, T., Ifegbesan, A.P., Rampedi, I.T., 2018. Household cooking fuel use patterns and determinants across southern Africa: evidence from the demographic and health survey data. Energy Environ. 29, 29–48. https://doi.org/10.1177/0958305X17739475.
Makonese, T., Masekameni, D.M., Annegarn, H.J., 2016. Energy use scenarios in an informal urban settlement in Johannesburg, South Africa. In: International Conference on the Domestic Use of Energy (DUE). IEEE, pp. 1–6.
Marlow, S., Dy, A.M., 2018. Annual review article: is it time to rethink the gender agenda in entrepreneurship research ? Int. Small Bus. J. 36, 3–22. https://doi.org/10.1177/0266242617738321.
Masera, O.R., Saatkamp, B.D., Kammen, D.M., 2000. From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model. World Dev. 28, 2083–2103.
Matter, K.J., 2016. The persistence of Residential Energy Insecurity in Manufactured Housing of Minnesota: A Grounded Theory Study of the Social, Policy and Structural Dimensions. The Univerity of Minnesota, US.
Memmott, T., Carley, S., Graff, M., Konisky, D.M., 2021. Sociodemographic disparities in energy insecurity among low-income households before and during the COVID-19 pandemic. Nat. Energy 6, 186–193. https://doi.org/10.1038/s41560-020-00763-9.
Merten, M., 2019. Electricity Prices Goes up Way beyond Inflation as Raphosa Answers Question on Eskom in the House [WWW Document]. Dly. Maverick. URL, 9.29.20. https://www.dailymaverick.co.za/article/2019-03-08-electricity-price-goes-up-way-beyondinflation-as-ramaphosa-answers-questions-on-eskom-in-the-house/#gsc.tab=0.
Mgwambani, S.L., Kasangana, K.K., Makonese, T., Masekameni, D., Gulumian, M., Mbonane, T.P., 2018. Assessment of household energy poverty levels in Louiville, Mpumalanga, South Africa. In: International Conference on the Domestic Use of Energy (DUE). IEEE, pp. 1–7.
Mhlanga, D., Garidzirai, R., 2020. Energy demand and race explained in South Africa: a case of electricity. Eurasian J. Bus. Manag. 8, 191–204. https://doi.org/10.15604/ejbm.2020.08.03.003.
Middlemiss, L., Gillard, R., 2015. Fuel poverty from the bottom-up : characterising household energy vulnerability through the lived experience of the fuel poor. Energy Res. Soc. Sci. 6, 146–154. https://doi.org/10.1016/j.erss.2015.02.001.
Mpeta, B., Fourie, J., Inwood, K., 2018. Black living standards in South Africa before democracy: new evidence from height. South Afr. J. Sci. 114, 1–8.
Munien, S., Ahmed, F., 2012. Gendered perspective on energy poverty nd livelihoods - advancing the Millennium Development Goals in developing countries. Agenda 26, 112–123. https://doi.org/10.1080/10130950.2012.674252.
Nathan, D., Shakya, I., Rengalakshmi, R., Manjula, M., GaIkwad, S., Kelkar, G., 2018. The value of rural women's labour in production and wood fuel use-a framework for analysis. Econ. Polit. Wkly. 53.
Núñez-Peiró, M., Sánchez, C.S.G., Sanz-Fernández, A., Gayoso-Heredia, M., López-Bueno, J.A., González, F.J.N., Linares, C., Díaz, J., Gómez-Muñoz, G., 2021. Exposure and vulnerability toward summer energy poverty in the city of Madrid: a gender perspective. In: Smart and Sustainable Planning for Cities and Regions, pp. 481–495. https://doi.org/10.1007/978-3-030-57332-4_34.
Nwosu, C.O., Catherine, N., 2018. Female Household Headship and Poverty in South Africa: an Employment-Based Analysis (No. ERSA Working Paper 761). Cape Town, South Africa.
O'Dell, K., Peters, S., Wharton, K., 2014. Women, Energy and Economic Empowerment [WWW Document]. Atl. URL, 6.10.21. https://www.theatlantic.com/sponsored/deloitte-shifts/women-energy-and-economic-empowerment/261/.
Odeku, K.O., Meyer, E., 2019. Socioeconomic implications of energy poverty in South African poor rural households. Acad. Enterpren. J. 1, 1–2.
Ozughalu, U.M., Ogwumike, F.O., 2019. Extreme energy poverty incidence and determinants in Nigeria : a multidimensional approach. Soc. Indicat. Res. 142, 997–1014. https://doi.org/10.1007/s11205-018-1954-8.
Papada, L., Kaliampakos, D., 2019. Development of vulnerability index for energy poverty. Energy Build. 183, 761–771. https://doi.org/10.1016/j.enbuild.2018.11.033.
Phillips, J., Petrova, S., 2021. The materiality of precarity: gender, race and energy infrastructure in urban South Africa. Environ. Plann. A 53, 1031–1050. https://doi.org/10.1177/0308518X20986807.
Pueyo, A., Carreras, M., Ngoo, G., 2020. Exploring the linkages between energy, gender, and enterprise: evidence from Tanzania. World Dev. 128, 104840. https://doi.org/10.1016/j.worlddev.2019.104840.
Pueyo, A., Maestre, M., 2019. Linking energy access, gender and poverty: a review of the literature on productive uses of energy. Energy Res. Soc. Sci. 53, 170–181.
Rathi, S.S., Vermaak, C., 2018. Rural electrification, gender and the labor market: a cross-country study of India and South Africa. World Dev. 109, 346–359. https://doi.org/10.1016/j.worlddev.2018.05.016.
Robinson, A.L.E.A., 2017. Ethnic diversity, segregation and ethnocentric trust in Africa. Br. J. Polit. Sci. 50, 217–239. https://doi.org/10.1017/S0007123417000540.
Robinson, C., 2019. Energy poverty and gender in England: a spatial perspective. Geoforum 104, 222–233. https://doi.org/10.1016/j.geoforum.2019.05.001.
Ruse, J.L., Stockton, H., Smith, P., 2019. Social and health-related indicators of energy poverty: An England case study. In: Fabbri, K (Ed.), National Energy Action. Academic Press, Newcastle Upon Tyne, United Kingdom.
SAHO, 2021. Race and Ethnicity in South Africa [WWW Document]. URL, 9.19.20. https://www.sahistory.org.za/article/race-and-ethnicity-south-africa.
Scarpellini, S., Rivera-Torres, P., Suárez-Perales, I., Aranda-Usón, A., 2015. Analysis of energy poverty intensity from the perspective of the regional administration: empirical evidence from households in southern Europe. Energy Pol. 86, 729–738.
StatsSA, 2017. Sustainable Development Goals: Indicator Baseline Report 2017 - South Africa. Statistics South Africa, Pretoria, South Africa.
StatsSA, 2016. General Household Survey. https://doi.org/10.1016/S0022-5223(12)00629-0. Pretoria, South Africa.
Tchereni, B.H., Grobler, W., Dunga, S.H., 2013. Economic analysis of energy poverty in South Lunzu, Malawi. Econ. Anal. 4.
UN, 2019. The Sustainable Development Goals Report. https://doi.org/10.29171/azu_acku_pamphlet_k3240_s878_2016. Geneva.
UN Women, 2018. Why gender equality matters across all SGDs. In: Turning Promises into Action: Gender Equality in the 2030 Agenda for Sustainable Development. United Nations, Geneva, p. 72.
Wang, K., Wang, Y.X., Li, K., Wei, Y.M., 2015. Energy poverty in China: An index based comprehensive evaluation. Renew. Sustain. Energy Rev. 47, 308–323. https://doi.org/10.1016/j.rser.2015.03.041.
Wee, R.Y., 2019. Most ethnically diverse countries. In: The World.
Winther, T., Ulsrud, K., Matinga, M., Govindan, M., Gill, B., Saini, A., Brahmachari, D., Palit, D., Murali, R., 2020. In the light of what we cannot see: exploring the interconnections between gender and electricity access. Energy Res. Soc. Sci. 60, 101334.
Wong, Y.N., 2012. World development report 2012: gender equality and development. In: Forum for Development Studies. Taylor & Francis, pp. 435–444.
World Elections, 2014. Race, Ethnicity and Language in South Africa [WWW Document]. URL, 9.19.20. https://welections.wordpress.com/guide-to-the-2014-south-african-election/race-ethnicity-and-language-in-south-africa/.