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JEL Classification

D14, O13, Q40, Q53

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Place-Based Energy Inequality for Ethnicities in Nepal

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Abstract

This paper assesses ethnic differences for four energy outcomes using a survey of 6,000 households in Nepal. These four outcomes are avoiding open wick lamps, having a solar lighting system, living in a neighbourhood with street lighting, and having a connection to the national grid. We find large differences across ethnic groups, with the Madhesi group having distinct energy outcomes, for each of the four dimensions. However, progressively more detailed locational variables explain much of the difference. Our interactive analysis then suggests that some of the remaining variation is explained by socioeconomic variables of having a financial account, school attendance, or membership of a women's group. However, ethnic inequality for the most place-based outcome, of living in an area with street lighting, is not reduced by education or women's group membership. Our results therefore suggest that ethnic inequality in place-based energy outcomes may not be addressed by policies promoting education and community group participation. Policies to increase the proportions of households with access to financial accounts may have broader effectiveness in reducing ethnic energy inequality across many energy dimensions.

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1. Introduction

A crucial aspect of energy justice involves ensuring access to sustainable energy types for everyone, as stated in goal seven of the United Nations Sustainable Development Goals (UN SDGs). This is important in relation to sustainability and climate change mitigation at a societal level. Energy justice also involves households having access to affordable, clean, and reliable energy sources. In contrast, reliance on polluting appliances such as open wick lamps using kerosene, can present health risks for household occupants. If some social groups do have adverse energy outcomes on average, it presents the possibility of energy injustice and would be a failure to meet the UN SDGs. We consider the differences in energy outcomes for ethnic groups in Nepal to assess the extent of differences and reasons for these differences.

Research on ethnic or racial inequality has rarely been a focus of prior studies on energy economics. This provides an opportunity for new studies to add substantial value when building on the limited amount of prior analysis. We investigate the potential for ethnic energy inequality across four key dimensions in Nepal, including both place-based outcomes and household-specific outcomes. While there are major ethnic differences, our analysis reveals that much of the variation in each energy outcome is based on geographical concentration of some ethnic groups. We then show which key socioeconomic variables can further account for some ethnic differences. This reveals a key difference between place-based and household specific energy outcomes, with social variables reducing household-specific inequality but not place-based inequality. This has major policy relevance, since policies can then be aligned with the key socio-economic aspects which can reduce ethnic inequality in energy outcomes.

Prior studies have also recently begun to consider ethnic impacts on energy outcomes, although the focus has primarily been on a limited number of energy aspects such as energy poverty. For example, there is evidence that ethnic fractionalization is linked with energy poverty in Nepal (Paudel, 2021), but that ethnic diversity lowered energy poverty in South Africa after apartheid (Koomson et al., 2022). However, there is also evidence that employment precarity contributes to energy poverty being elevated among Black South Africans (Koomson and Awaworyi Churchill, 2022). In the US, there is evidence that energy poverty is more likely for African-American households (Best, 2022; Dogan et al., 2022). Energy poverty also differs substantially by ethnicity in developing nations, including Sri Lanka (Jayasinghe et al., 2021).

There are also a growing number of studies which include race or related characteristics as an explanatory variable while focusing on other aspects and energy outcomes. For instance, Rahut et al. (2022) found that ethnic minorities have been disadvantaged for the use of clean cooking fuel in Nepal. Studies explaining solar-panel uptake have also included explanatory variables related to ethnicity in some cases. Some of these solar studies find insignificant coefficients for the US (Best and Esplin, 2023; Corbett et al., 2022; Drury et al., 2012; Graziano et al., 2019; Horne et al., 2021), Sweden, and India (Irfan et al., 2021; Mundaca and Samahita, 2020; Urpelainen and Yoon, 2015).

There are also studies finding significant impacts related to ethnicity, mostly using aggregated data. For instance, country of birth has significant impacts in studies for Australia (Best and Trück, 2020) and Belgium (de Groote et al., 2016; de Groote and Verboven, 2019). Significance exists for ethnicity in Sri Lanka also (McEachern and Hanson, 2008). Many US studies also show significant ethnic impacts (Bollinger and Gillingham, 2012; Davidson et al., 2014; Dong et al., 2017; Graziano and Gillingham, 2015; Hughes and Podolefsky, 2015; Kurdgelashvili et al., 2019; Kwan, 2012; Reames, 2020; Sunter et al., 2019).

In addition, some studies using household-level data also find significant influences of ethnicity on solar-panel uptake. This evidence exists across Europe (Curtius et al., 2018; Halleck Vega et al., 2022; Niamir et al., 2020; Strazzera and Statzu, 2017), Africa (Rahut et al., 2018), and

South Asia (Aklin et al., 2018). Ethnic differences are also evident using household data in the US (Mildenberger et al., 2019).

Mixed prior results might relate to the multiple possible channels that could explain ethic inequality in energy outcomes. One is that underlying socio-economic differences are important. For example, employment differences explain some of the ethnic variation in energy poverty in South Africa (Koomson et al., 2022), while wealth and housing differences are important in the US for the solar-panel context (Best, 2022; Best and Esplin, 2023). Another suggested channel is ethnic bias, such as where a lack of diverse representation in decision-makers at solar installation firms could lead to lower deployment in minority neighbourhoods (Nature Energy Editorial, 2020). Place-based biases might also be possible, such as lower circuit hosting capacity in US census block groups that are “Black-identifying and disadvantaged” (Brockway et al., 2021).

Our paper considers the possibility of ethnic disparity for four different energy outcomes. This is valuable given the potential for inequality to vary across contexts. A single study with a common sample and method can investigate differences across energy outcomes in a consistent manner. The value of this approach has been evident for the US, where there appears to be greater ethnic variation in energy poverty than for solar-panel uptake (Best, 2022). This paper extends the analysis by considering place-based outcomes of neighbourhood street lighting and connections to national grids, in addition to more household-centric outcomes of investment in solar lighting or avoidance of open wick lamps. The avoidance of polluting energy types which can harm health, such as the use of open wick lamps fuelled by kerosene, is an important part of achieving the UN SDG 7.

2. Energy Justice and Ethnic Inequality

McCauley et al. (2013) first conceptualised energy justice as providing “all individuals, across all areas, with safe, affordable and sustainable energy”. This early definition is supplemented by a practical framework across energy life cycles or systems concerning three central tenets: *distributional*, *procedural*, and *recognition justice* (Heffron and McCauley, 2017). These “triumvirate of tenets” are supplemented by two additional forms of energy justice: *Cosmopolitanism justice* which considers energy system effects from a global perspective and *Restorative justice* which requires rectification of injustices based on legal accountability for grievances across the energy life cycle (Heffron et al., 2021). A second formulation of energy justice is the principle-based approach which advances eight core principles: availability; affordability; due process; transparency and accountability; sustainability; intra-generational equity; inter-generational equity; and responsibility (Heffron, 2021). The combination of the energy justice tenets and principles-based approaches are illustrated in Figure 1 below:

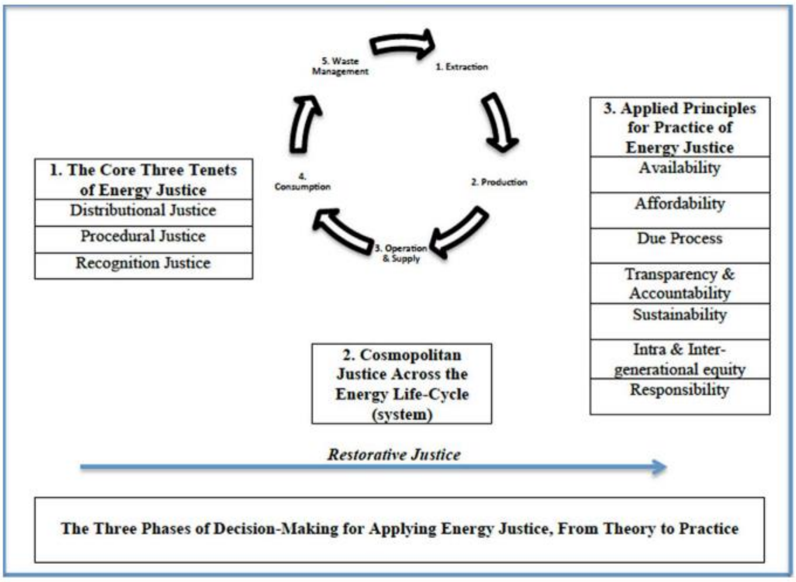

Figure 1: The Energy Justice Conceptual Framework
Source: Figure adopted from (Heffron and McCauley, 2017, p. 660)

Both the tenets and principles-based formulation of energy justice offer a three-part practical methodology for examining energy injustices linked to ethnic inequality. First, energy justice is a *conceptual tool* for analysing distinct subjective place-based energy justice concerns, an *analytical tool* to examine values embedded within a particular energy system, and a *decision-making tool* to inform future legal and policy decision making (Jenkins, 2018; Sovacool and Dworkin, 2015). This methodological foundation of academic and policy relevance distinguishes energy justice from environmental and climate justice derived from social movements (Jenkins, 2018).

Much of the literature to date is limited to framing energy justice as a conceptual tool or an examination of energy poverty linked to ethnicity (Koomson et al., 2022; Churchill and Smyth, 2020; Paudel, 2021; Dogan et al., 2022). This scholarly gap has led to calls for more practical applications of energy justice as an analytical and decision-making tool to deliver policy outcomes (Heffron, 2021). Studies applying energy justice to developing jurisdictions include rural electrification in the Pacific (Taylor and Taylor, 2022) and Africa (Gafa et al., 2022), bioenergy development in Nepal (Damgaard et al., 2017), and analysis of Nepal's national energy policies (Islar et al., 2017). Given this background, our study seeks to fill this evident gap in the literature by applying energy justice to assess ethnic differences for four energy outcomes in Nepal. This interactive analysis probes the *distribution* of energy solutions based upon ethnicity and *restorative justice* to assess ethnical and spatial energy inequality. Munro et al. (2017) highlights the role of *distribution justice* in particular as a "socio-spatial concept directing attention to patterns in the location and dissemination of energy goods and ills".

Dissemination of *distribution* and *restorative justice* as an *analytical tool* can result in *decision-making tools* to redress energy poverty linked to ethnic inequity. The study results indicate practical policies to encourage energy justice and reduce ethnic inequality across four energy outcomes by examining avenues to execute *restorative justice* as a result of *distribution* *injustices*. To measure objective energy justice we analyse data produced by a Nepal-based survey firm, funded and published by the World Bank. The survey provides for a distribution and restorative analysis to reflect the level of racial inequality for open wick lamp usage, solar lightening systems, street lighting in neighbourhoods, and households with connections to the national grid.

3. Data and method

3.1 Household survey data

The paper uses a survey of 6,000 households conducted by a Nepal-based survey firm that was hired by the World Bank (ESMAP, 2019). The data collection was undertaken from July to December in 2017. It aimed to provide wide coverage across Nepal and recorded multiple locational variables. These were based on regional classifications that existed at the time of the 2011 Census, along with updated locational information following changes to administrative regions. For example, the data contains households from 71 of the 75 districts that had been defined in the 2011 Census and for seven provinces.

The sample size and selection was informed by general World Bank benchmarks such as 3,500 households for the representative national-level survey. For the survey on Nepal, the sample size was higher at 6,000 to allow for reliable estimates for sub-national categories such as ecological regions. We also conduct regression analysis which can control for locational details when trying to isolate influences from socio-economic variables. The sample selection was based on two-stage stratification. The first stage included random selection of wards to be representative of urban and rural areas and ecological regions. The second stage involved selection of 15 households from the 400 selected wards, with an aim of including enough households without a grid connection.

The key variables from the data are summarized in Table 1. We display the proportion of the sample with each characteristic for the binary variables used in our analysis. For example, 84% of the sample did not use an open wick lamp, which is an outcome that can avoid adverse health implications. Three other favourable energy outcomes include having a solar lighting system (27% of the sample), neighbourhoods having street lighting (14%) and households having a connection to the national grid (67%). One example of an explanatory variable is the household having a financial account, which applies in 73% of the cases. In addition, we use numerical variables such as the age of the respondent (minimum=19; mean=49.5; maximum=96) and the number of household members (minimum=1; mean=4.6; maximum=31). In the results section, street lights and grid connections are also used in explanatory variables when explaining use of open wick lamps and investment in solar-lighting systems. Grid connections are also used as an explanatory variable when explaining street lights. When explaining national grid connections, mini-grids are not used as an explanatory variable, since the direction of causation is likely to be that the absence of the national grid would promote incentives for mini grids.

Table 1. The proportions of the sample with each characteristic

Variable	Proportion
Dependent	
Not using open-wick lamp	0.84
Has solar-lighting system	0.27
Neighbourhood has street lighting	0.14
Connection to the national grid	0.67
Controls	
Dwelling owned by resident	0.995
Has a financial account (formal or informal)	0.73
Owns agricultural land	0.79
The respondent is self-employed	0.51
The respondent has no schooling	0.40
The respondent is female	0.20
Connection to a mini grid	0.14
Ethnicity	
Ethnicity is Brahmin	0.15
Ethnicity is Chhetri	0.24
Ethnicity is Janajati	0.17
Ethnicity is Madhesi	0.12
Other ethnicity	0.31
Ethnicity is non-Madhesi	0.88
Ethnicity is Madhesi; no financial accounts held	0.04
Ethnicity is Madhesi; holds financial account	0.08
Ethnicity is Madhesi; no schooling	0.06
Ethnicity is Madhesi; has attended school	0.06
Location	
Rural	0.45
Urban	0.55
Mountain	0.19
Hill	0.40
Hill Kathmandu	0.10
Terai	0.31

Notes: There are 6,000 observations. Ethnicities of “Janajati Magar”, “Janajati Newar”, and “Janajati Sherpa” are included in the “Other” category rather than the group separately labelled in the data as “Janajati”. Locational variables for districts and municipalities include binary variables for 71 districts and 343 municipalities (we use these in separate estimations).

3.2 Method

The econometric estimations use a linear probability model, as outlined in equation (1). Similar results can be obtained with probit and logit models when including concise locational controls. However, a linear probability model has an advantage in this instance of allowing for very detailed locational controls to be analysed with the full sample, including municipality binary variables. Only 15 surveyed households are in many municipalities, meaning that some energy outcomes do not vary across some municipalities. While probit and logit models will drop households in these cases, a linear probability model can retain the full sample.

$$N_h = \alpha + \beta \boldsymbol{E'}_h + \gamma \boldsymbol{O'}_h + \varepsilon_h \qquad (1)$$

The analysis uses four separate dependent variables (*N*) for energy outcomes. One is a binary variable equal to one for households in neighbourhoods with street lighting. This is the most place-based energy outcome of our four dependent variables: every household in a given place experiences a similar outcome. Another aspect which has some strong area influences is a binary variable equal to one for connection to the national grid. This second variable is not entirely place-based, as households may not be connected to the national grid when it is readily available. The other two dependent variables are more household-centric, in that decisions are more determined by household-specific issues. One variable relates to the use of open wick lamps, and the other is investment in solar-lighting systems. Even though household-level variation is important in these cases, there is still some geographical influence. For instance, solar-lighting systems are more likely in rural areas where electricity grids are less likely to be available.

Key explanatory variables relate to ethnicity (*E*). The data includes 12 different categories, although we combine some categories since there are very few households in several categories. In particular, we start by assessing the four groups with the most households and combining the remaining groups into a fifth ‘other’ category. We then focus on the Madhesi group with a binary variable, since this group appears to have distinct energy outcomes.

An important part of the empirical strategy is to include progressively more detailed locational variables. We start with a rural/urban binary variable and then progress to a four-category variable for the Ecological region as either Mountain, Hill, Hill Kathmandu, or Terai (plains). These geographical variables are likely to be important for energy in numerous ways, such as different climatic conditions and different proximity to electricity grids. We also include much more detailed locational variables for 71 districts and 343 municipalities. Figure 1 shows district boundaries and the four ecological regions. It captures the extra degree of detail that is realised for the locational variables when switching from four binary variables to 71 for each district (four districts were not covered by the survey). In Section 3, we progress further with 343 binary variables for municipalities.

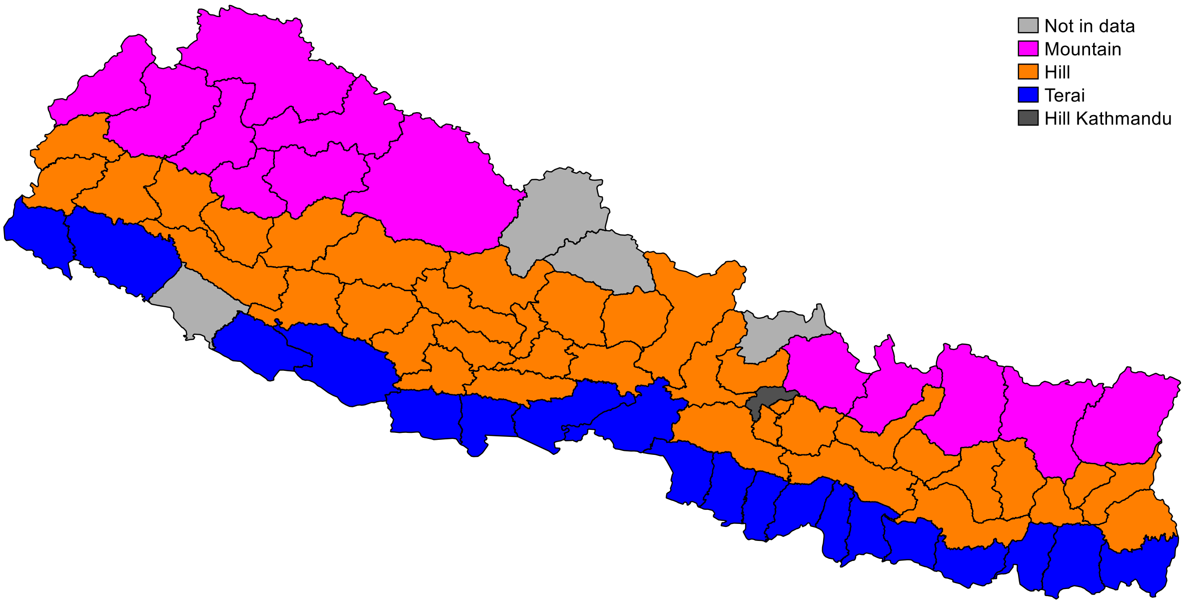

Figure 2. Districts in Nepal, with ecological regions identified. Data: ESMAP (2019), (International Steering Committee for Global Mapping and Nepal., 2022)

We also assess a range of socioeconomic variables that have been assessed in prior studies, based on their intuitive relevance for household decision making. Having access to financial accounts may promote some energy outcomes, such as investment in solar lighting systems (Best and Nepal, 2022). Our results in Section 3 use a binary variable equal to one for households who have accounts with either formal financial institutions or with informal institutions. We also control for education with a binary variable which distinguishes whether the respondent has ever been to school. One set of results also has membership of any women's community group as part of the explanatory variables, as this has been shown to promote investment in solar lighting systems (Best and Nepal, 2022). This community participation aspect is not included for most of our results since some households did not respond for the relevant survey question. A range of other socio-economic and demographic variables are also included for the *O* vector in equation (1), as listed in Table 1.

3.3 Potential econometric issues

Omitted variable bias is a general concern for studies of cross-sectional household surveys on energy and other topics. We seek to reduce these concerns with detailed control sets. In particular, we include many socio-economic and demographic controls, including key variables related to financial access and land ownership as a measure of wealth. One common variable not included is for income, based on data unavailability. Our inclusion of wealth and financial variables helps to lessen concerns around income, since accumulated resources are more likely to be important when considering upfront costs for large investments such as solar-lighting systems or connections to electricity grids.

A second part of our strategy in relation to potential omitted variables is use of extensive locational controls. This includes binary variables for 343 municipalities in some regressions. These are useful to account for unobserved heterogeneity which is difficult to measure through other specific variables. The *R*-squared values in Section 3 when using these detailed locational controls are high in comparison to usual values when investigating energy uptake with household-level surveys.

The third part of the approach for addressing concerns on omitted variables relates to the nature of our research question. We seek to understand reasons for observed differences for energy outcomes across ethnicities, rather than estimating precise ethnicity effects. It is likely to be a very difficult challenge for all studies to precisely isolate any ethnicity impacts from other correlated socio-economic and demographic influences. Instead, we show that major ethnic differences in energy outcomes are reduced substantially with progressively more detailed locational controls. Remaining ethnic variation is then partly explained by key socio-economic variables for having financial accounts and for having attended school.

A potential downside of including many explanatory variables is the possible influence of multi-collinearity. However, the key issue is the extent of the multi-collinearity. Moderate correlations between explanatory variables may lead to higher standard errors and some challenges for producing precise estimates, but this may be manageable. We can check for the extent of the multi-collinearity by reporting variance inflation factors and then ensuring that the values are below acceptable thresholds of 5 or 10. Our paper also does not feature the simultaneous inclusion of both income and wealth, which has been noted as an issue in some contexts (Kucher et al., 2020).

Reverse causation is a further potential issue to consider. For instance, households may have a connection to a mini grid as a substitute for a connection to the national grid. It is possible that that the national grid being unavailable could promote mini grids. We therefore do not include mini-grid connections as an explanatory variable when investigating connections to the national grid. However, we do include mini grids when explaining other outcomes such as solar-lighting system investment, since households may be more motivated to get a solar-lighting system when they have no alternative sources of electricity.

4. Results

Table 2 shows the influence of ethnicity on the use of open wick lamps. Each column has an extensive control set which includes the variables in Table 1. More comprehensive display of non-ethnicity coefficients is given in Appendix Table A.1. Each column of Table 2 has a different degree of detail for locational controls. The regression in column (1) starts with a binary urban/rural variable. Column (2) instead has three Ecological regions of Hill, Hill Kathmandu, and Terai. The omitted reference is the Mountain region. Column (3) has binary variables for 71 districts, while column (4) has 343 municipalities.

Table 2 indicates that there are large differences in the use of open wick lamps across ethnicity groups. The dependent variable is equal to zero when the respondent reported using an open wick lamp and one otherwise. This gives a higher value for a more favourable outcome, given that the use of these lamps can have adverse health consequences. Other lighting sources, such as solar lighting systems, can be better from a health perspective. The Chhetri group are more likely to achieve the beneficial outcome of avoiding use of open wick lamps, with a three-percentage-point difference with the Brahmin reference group based on column (1). In contrast, the Madhesi group appear to be much less likely to achieve the outcome of avoiding use of open wick lamps. The magnitude of the difference between the Madhesi and Brahmin groups is 32 percentage points in column (1), suggesting substantial ethnic inequality when controlling for locational differences with a binary variable.

More specific locational variables have substantial impacts on the coefficients for some ethnicity coefficients including for the Chhetri group, but especially for the Madhesi group. The coefficient for the Madhesi group suggests a difference of eight percentage points with the Brahmin reference group in column (4) when controlling for municipality location, in contrast to the 32 percentage-point difference in column (1). The large locational impacts can be explained by the more frequent use of kerosene imports from India in the Terai region, which borders India. Nearly all of the Madhesi households live in this region. The coefficient for Madhesi households in column (1) can therefore be interpreted as partly being a proxy for this locational effect. The column (4) coefficient being lower likely suggests that ethnic differences are less pronounced when taking account of location in a more detailed way.

Table 2. The influence of ethnicity on *not* using open wick lamps

	Rural (1)	Region (2)	District (3)	Municip. (4)
Reference: Brahmin				
Chhetri	0.031**	0.025**	-0.005	-0.000
	(0.012)	(0.013)	(0.013)	(0.013)
Janajati	-0.017	-0.027*	-0.005	-0.028*
	(0.015)	(0.015)	(0.015)	(0.017)
Madhesi	-0.321***	-0.256***	-0.209***	-0.084***
	(0.021)	(0.023)	(0.028)	(0.032)
Other	-0.022*	-0.022*	-0.033***	-0.030**
	(0.013)	(0.013)	(0.012)	(0.013)
Control variables	Yes	Yes	Yes	Yes
Observations	6,000	6,000	6,000	6,000
Mean variance inflation factor	1.5	1.6	2.1	2.3
Adjusted R^2	0.124	0.135	0.265	0.361

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. Locational controls are progressively more detailed across the columns. Regression (1) uses a binary variable for rural or urban areas. Regression (2) instead controls for four Ecological regions. Regression (3) instead has 71 districts. Column (4) has 343 municipalities. "Control variables" refers to the control set which is evident in Table 1 plus age and number of occupants; results in Appendix Table A.1 provide coefficients for some control variables.

Table 3 reveals large differences in adoption of solar-lighting systems, compared to the reference ethnicity of Brahmin. Each of the significant coefficients are negative, suggesting that the Brahmin group has the highest uptake, when controlling for other variables. The two ethnicity groups with the largest differences to the Brahmin group are the Madhesi group and a composite group of other ethnicities. In column (1), the Madhesi group has lower uptake of solar-lighting systems by around 29 percentage points.

The benefit of having more specific locational controls appears to be evident again when comparing the columns of Table 3. The adjusted *R*-squared more than doubles from 0.226 in column (1) to 0.470 in column (4). The coefficients for the Madhesi group become substantially closer to zero while moving from column (1) to column (4). This may suggest that the coefficient in column (1) is acting as a proxy for locational variation. Solar-lighting systems are much less common in the Terai region, where most Madhesis live, in contrast to other more mountainous regions where grid substitutes are less available. With the more specific municipality variables in column (4), the Madhesi coefficient suggests a 10-percentage-point difference from the Brahmin group, rather than the 29 percentage points in column (1).

Table 3. The influence of ethnicity on uptake of solar lighting systems

	Rural (1)	Region (2)	District (3)	Municip. (4)
Reference: Brahmin				
Chhetri	-0.027	-0.035**	-0.017	-0.035*
	(0.018)	(0.018)	(0.018)	(0.019)
Janajati	0.011	0.008	0.020	-0.059***
	(0.019)	(0.020)	(0.020)	(0.021)
Madhesi	-0.290***	-0.209***	-0.134***	-0.102***
	(0.018)	(0.020)	(0.024)	(0.024)
Other	-0.093***	-0.087***	-0.056***	-0.076***
	(0.017)	(0.017)	(0.017)	(0.018)
Control variables	Yes	Yes	Yes	Yes
Observations	6,000	6,000	6,000	6,000
Adjusted R^2	0.226	0.232	0.311	0.470

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. Locational controls are progressively more detailed across the columns. Regression (1) uses a binary variable for rural or urban areas. Regression (2) instead controls for four Ecological regions. Regression (3) instead has 71 districts. Column (4) has 343 municipalities. “Control variables” match Table 2.

Figure 3 gives a visual summary of two key features: energy outcomes are much different for Madhesi households but large parts of the differences can be explained by locational factors. Two energy outcomes of not using open wick lamps (1) and adopting solar lighting systems (2) are shown in Figure 3. The coefficients from linear probability models are shown when controlling for the rural/urban split (R), four ecological regions (E), 71 districts (D), and 343 municipalities (M). In each case, the coefficients are negative and the 95% confidence intervals do not extend into positive territory. This indicates the differences between Madhesi energy outcomes and the reference group of Brahmin. The magnitudes in Figure 2 vary substantially from R1 for the Madhesi coefficient on not using open wick lamps when controlling for a binary rural variable, to M1 which instead controls for municipalities.

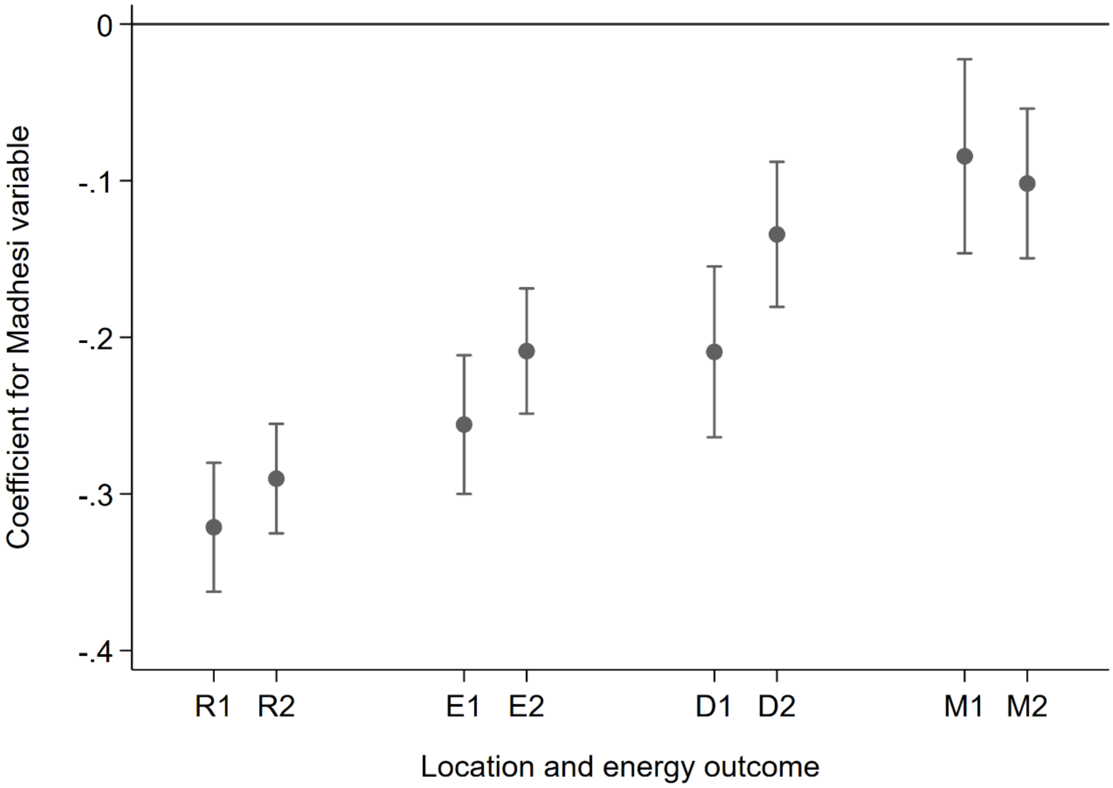

Figure 3. Coefficients for a binary Madhesi variable where the reference category is Brahmin. The coefficients are from the linear probability models in Table 2 and 3. The letters on the horizontal axis indicate the degree of detail of the locational variables: R=Rural/urban; E=Ecological Region; D=District; M=Municipality. The numbers are for energy outcomes: 1=not using open wick lamps; 2=investment in a solar lighting system.

Table 4 shows results for all four energy outcomes of avoiding use of open wick lamps, adopting solar lighting systems, living in areas with neighbourhood street lighting, and having a connection to the national grid. Table 4 switches to analyse a binary variable for Madhesi households compared to all other households. This implies that the Madhesi coefficients may be closer to zero, since the reference group now includes other households beyond only the Brahmin group. However, there are still negative and significant coefficients for the Madhesi binary variable. For the case of avoiding use of open wick lamps, the Madhesi coefficient of –0.063 in Table 4 is relatively similar to the corresponding coefficient of –0.084 in Table 2-column (4).

There are negative and significant coefficients for the Madhesi variable for each of the four energy outcomes in Table 4. The coefficient magnitudes are relatively similar in the range of four to six percentage points, relative to the reference group of all non-Madhesi households. This suggests that household-centric outcomes, such as choices on solar lighting systems by individual households, may not have different degrees of ethnic inequality to place-based outcomes like living in an area with neighbourhood street lighting. This similarity may not necessarily extend to other contexts.

Table 4 also shows two important variables that impact on energy outcomes. Having a financial account has a positive impact on all of the energy outcomes. Households with a financial account are more likely to avoid open wick lamps with a magnitude of around three percentage points and more likely to have a solar lighting system with a magnitude of six percentage points. The sign of these coefficients is intuitive since financial resources should give households the capacity to make beneficial energy investments, such as a switch away from open wick lamps and towards solar lighting systems. The positive coefficients for financial accounts in column (3) and (4) might suggest that households with financial accounts are more likely to live in areas with more favourable characteristics, such as neighbourhoods with street lights or easier access to the national grid. An adverse effect of a lack of education is suggested by the negative and significant coefficients for the ‘no school attendance’ variable in explaining each energy outcome.

Table 4. Linear probability models explaining four energy outcomes

	(1) NOWL	(2) SLS	(3) NSL	(4) NGC
Madhesi	-0.063**	-0.045**	-0.039*	-0.046*
	(0.030)	(0.019)	(0.022)	(0.025)
Financial account	0.032***	0.064***	0.027***	0.083***
	(0.012)	(0.011)	(0.006)	(0.010)
No school attendance	-0.049***	-0.035***	-0.020***	-0.038***
	(0.010)	(0.011)	(0.007)	(0.008)
Control variables	Yes	Yes	Yes	Yes
Location controls	Municipality	Municipality	Municipality	Municipality
Observations	6,000	6,000	6,000	6,000
Adjusted R^2	0.360	0.468	0.570	0.781

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. NOWL= no open wick lamp; SLS = solar lighting system; NSL= neighbourhood street lighting; NGC= national grid connection. The three displayed explanatory variables are binary. The reference ethnicity is ‘non-Madhesi’. “Control variables” match Table 2, except that street lights are not an explanatory variable in column (3) or (4) and column (4) also does not include mini-grid and national-grid explanatory variables.

Table 5 introduces a categorical variable which is like a type of interaction variable between the binary Madhesi variable and the key economic variable of having a financial account. To maintain the reference group as being all non-Madhesi households, as it is in Table 4, there are three categories for the new variable. These are (i) non-Madhesi; (ii) Madhesi and no financial accounts; (iii) Madhesi and having a financial account.

Table 5 shows that the difference (inequality) between Madhesi and non-Madhesi outcomes for the four energy aspects is primarily restricted to Madhesi households with no financial account. Each coefficient is negative and significant at the 1% level. The point estimates are also larger in absolute value terms compared to the coefficients in Table 4. In contrast, the coefficients for the group of Madhesi households with a financial account tend to be insignificantly different to zero in most cases. Having financial accounts may provide the capacity to overcome barriers faced by households without financial accounts, allowing for more beneficial energy outcomes.

Table 5. Linear probability model coefficients, including ethnicity 'interaction' terms

	(1) NOWL	(2) SLS	(3) NSL	(4) NGC
Reference: non-Madhesi				
Madhesi, no financial account	-0.157***	-0.067***	-0.073***	-0.157***
	(0.040)	(0.021)	(0.026)	(0.037)
Madhesi, with a financial account	-0.026	-0.039*	-0.026	-0.006
	(0.032)	(0.021)	(0.024)	(0.024)
Control variables	Yes	Yes	Yes	Yes
Location controls	Municipality	Municipality	Municipality	Municipality
Observations	6,000	6,000	6,000	6,000
Adjusted R^2	0.362	0.465	0.570	0.779

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. NOWL= no open wick lamp; SLS = solar lighting system; NSL= neighbourhood street lighting; NGC= national grid connection. "Control variables" match Table 4.

Table 6 focuses on the impact of Madhesi and education variables. Negative and significant coefficients are primarily driven by Madhesi households where the respondent had never attended school. There is statistical significance at the 1% level, except for column (3). The coefficients for Madhesi households with a respondent who has attended school tend to be closer to zero in most case and are insignificantly different to zero in two cases. The results in Table 6 suggest that education may not be effective in reducing some place-based inequality. Column (3) shows that Madhesi households with a respondent having attended school appear to be less likely to live in neighbourhoods with street lights.

Table 6. Linear probability model coefficients, including ethnicity-education 'interactions'

	(1) NOWL	(2) SLS	(3) NSL	(4) NGC
Reference: non-Madhesi				
Madhesi, no school	-0.145***	-0.055***	-0.028	-0.082***
	(0.035)	(0.020)	(0.023)	(0.030)
Madhesi, school attendance	-0.001	-0.040*	-0.049*	-0.021
	(0.033)	(0.021)	(0.025)	(0.026)
Control variables	Yes	Yes	Yes	Yes
Location controls	Municipality	Municipality	Municipality	Municipality
Observations	6,000	6,000	6,000	6,000
Adjusted R^2	0.362	0.467	0.570	0.781

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. NOWL= no open wick lamp; SLS = solar lighting system; NSL= neighbourhood street lighting; NGC= national grid connection. "Control variables" match Table 4.

Table 7 has similar analysis but considers whether a household member is part of a women's community group of any kind (42% of the sample). For Madhesi households with a member of a women's group, the coefficients are insignificant, except for column (3). This conveys a similar concept as in Table 6, where social inclusion or advance does not appear to address the place-based inequality relating to living in a neighbourhood with street lights. In contrast, membership of a women's group does appear to help to reduce the inequality for other energy dimensions in columns (1), (2), and (4). These other energy dimensions directly involve household-level decisions, in contrast to the neighbourhood-level variable for street lighting.

Table 7. Linear probability model coefficients, with ethnicity-women's group 'interactions'

	(1) NOWL	(2) SLS	(3) NSL	(4) NGC
Reference: non-Madhesi				
Madhesi, not in a women's group	-0.070**	-0.056***	-0.021	-0.067**
	(0.032)	(0.019)	(0.023)	(0.027)
Madhesi, in a women's Group	-0.061	-0.019	-0.089***	-0.008
	(0.043)	(0.029)	(0.029)	(0.026)
Control variables	Yes	Yes	Yes	Yes
Location controls	Municipality	Municipality	Municipality	Municipality
Observations	5,950	5,950	5,950	5,950
Adjusted R^2	0.363	0.468	0.571	0.784

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. NOWL= no open wick lamp; SLS = solar lighting system; NSL= neighbourhood street lighting; NGC= national grid connection. "Control variables" match Table 4. Households did not respond about membership of women's groups in 50 instances, leading to a slightly smaller sample size of 5.950.

5. Discussion and implications

The first set of contributions of the paper relates to locational variables. We show that there is a large impact of different locational variables, even when including substantial control sets of other variables. While there are very major differences in energy outcomes across ethnicities, this is largely based on locational clustering of ethnicities. We show that the magnitudes of the ethnicity coefficients are substantially reduced when including more detailed locational variables. The most detailed locational controls in our paper are for 343 municipalities, resulting in high proportions of variation being explained by the models.

The second main contribution is the consistent analysis of four different energy outcomes. This is important given that prior studies of ethnicity impacts on energy outcomes tend to have a narrower focus, such as on an energy poverty variable. The four energy aspects that we investigate cover both place-based (neighbourhood street lights) and household-centric (avoiding open wick lamps and investing in solar lighting systems) variables. This is important based on the relation to two key types of channel through which ethnic inequality could be perpetuated. That is, there could be disadvantage faced by individual households of an ethnic group, or there could be inferior outcomes for whole areas which have clusters of particular ethnicities. We do not find evidence of major differences between the household-centric and place-based inequality. However, we do find evidence that socio-economic variables have different influences when interacted with a Madhesi variable. Having financial accounts lowers all four types of energy inequality across ethnicities but social variables do not.

The third main contribution is focusing on households having a financial account as a policy-relevant variable for policymakers seeking to reduce ethnic inequality in energy outcomes. We show that ethnic inequality tends to be most pronounced among households without financial accounts. This result suggests that ethnic inequality across multiple energy outcomes can be reduced through greater financial inclusion. Policy to promote households having financial accounts is more feasible in the short term than other policy suggestions such as removing economic inequality.

The fourth contribution is the finding of the differing impact of social variables for place-based and household-centric energy inequality. Education and membership of a women’s group are linked to less ethnic inequality for household-centric outcomes such as avoiding open-wick lamps and having a solar-lighting system. However, the place-based aspect of living in a neighbourhood with street lighting does not display the same favourable outcome. The difference in the influence is intuitive: knowledge through school and social groups can promote better household decisions but it does not directly influence place-based decisions by governments or energy-system planners. This has substantial policy implications, as social inclusion policies may be effective for household-centric aspects, but not place-based aspects.

Future research can consider a range of other energy outcomes in many countries. These other energy outcomes include a range of energy poverty variables, given the multi-dimensional nature of the concept. Studies of other countries, including of developing countries, can assess whether ethnic impacts are different across countries. Research on developed countries can also consider inequality across ethnicities for investment in electric vehicles or home batteries. Future research can also focus on the distinction between place-based and household-centric inequality. For instance, studies of community energy investment might focus on place-based inequality.

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Table A.1. The influence of ethnicity on *not* using open wick lamps, controls shown

	Rural (1)	Region (2)	District (3)	Municip. (4)
Reference: Brahmin				
Chhetri	0.031**	0.025**	-0.005	-0.000
	(0.012)	(0.013)	(0.013)	(0.013)
Janajati	-0.017	-0.027*	-0.005	-0.028*
	(0.015)	(0.015)	(0.015)	(0.017)
Madhesi	-0.321***	-0.256***	-0.209***	-0.084***
	(0.021)	(0.023)	(0.028)	(0.032)
Other ethnicity	-0.022*	-0.022*	-0.033***	-0.030**
	(0.013)	(0.013)	(0.012)	(0.013)
No street lights	-0.092***	-0.078***	-0.057***	-0.017
	(0.011)	(0.011)	(0.012)	(0.013)
No national grid connection	-0.024*	-0.044***	-0.148***	-0.229***
	(0.014)	(0.014)	(0.017)	(0.023)
Dwelling not owned	0.005	0.006	-0.024	-0.002
	(0.051)	(0.054)	(0.044)	(0.046)
Financial account	0.041***	0.038***	0.038***	0.030***
	(0.012)	(0.012)	(0.011)	(0.012)
Own agricultural land	0.006	0.003	0.016	0.010
	(0.012)	(0.012)	(0.011)	(0.011)
Self-employment	0.036***	0.037***	0.023***	0.006
	(0.009)	(0.009)	(0.009)	(0.009)
No schooling	-0.042***	-0.041***	-0.048***	-0.046***
	(0.012)	(0.012)	(0.011)	(0.011)
Respondent age	-0.000	-0.001	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Female respondent	0.048***	0.045***	0.034***	0.030***
	(0.012)	(0.012)	(0.011)	(0.010)
Number of occupants	0.001	0.002	0.000	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Mini-grid connection	0.060***	0.044***	0.057***	0.017
	(0.015)	(0.015)	(0.018)	(0.029)
Observations	6,000	6,000	6,000	6,000
Mean variance inflation factor	1.5	1.6	2.1	2.3
Adjusted R^2	0.124	0.135	0.265	0.361

Notes: ***, **, * represent statistical significance at the 1%, 5%, and 10% levels respectively. Locational controls are progressively more detailed across the columns. Regression (1) uses a binary variable for rural or urban areas. Regression (2) instead controls for four Ecological regions. Regression (3) instead has 71 districts. Column (4) has 343 municipalities.