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Research Article

Exploring the Causal Relationship between Time Use Behavior and Residential Electricity Consumption in Central Punjab, Pakistan

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Abstract

The current paper studies the causal relation between the time-use behavior, which is the daily allocation of time spent at work, at home, at leisure, and resting, and the residential energy consumption, in the cities of Lahore and Faisalabad, Pakistan. With an increase in energy use and urban populations, determining behavioral determinants of electricity use is vital to demand-side energy management approaches. Using 200 households that were sampled using structured recall time-use surveys, the study presents a combination of descriptive statistics and Oaxaca-Blinder decomposition to analyse the findings. As its title suggests, it investigates the influence of socioeconomic dimensions, time use, ownership of appliances, and energy consciousness on the pattern of electricity consumption. Stratified random sampling was applied to secure representation of levels of income and types of households. Results indicate that the majority of respondents consume more than 12 hours at home on working days, and energy consumption is directly connected to time use patterns, conservation habits, and awareness of appliance efficiency. More than half of the energy-conscious households implemented the energy-saving technologies: solar panels, knowledge of time-of-use tariffs, and change of inefficient appliances. The decomposition analysis indicates a forced consumption gap that appears between Lahore and Faisalabad. The one that is explained is associated with individualistic and observable aspects of ownership of appliances and family structure, whereas the not explained part is composed of contextual and behavioural factors reflective of informal economies, flexible lifelines, and social norms.
Keywords: Time use behavior, Oaxaca Blinder Decomposition, Sankey time use visualization, Energy consumption behavior, Energy efficiency awareness, Central Punjab, Lahore, Faisalabad.

Introduction

Fossil fuels, nuclear energy, and renewables represent the sources of inputs that exceed energy in producing goods and services. The usage of energy in developing economies like the economy of Pakistan relates closely with economic development, whereby all sectors, agriculture, industry, and services, can only afford to use cost-effective energy and one that is available on demand. Besides other factors like income level and efficiency of appliances, time use behavior is also a significant determinant of residential electricity consumption. The energy needs pattern reflects on the way people orient their time in employment, home environment, and leisure, especially in housing units. This information on the behavioral pattern is crucial for coming up with sound energy management processes and sustainable consumption patterns. As Nisha et al. (2023) note, energy is amongst the most critical components of national infrastructure and affects the level of productivity, cost distribution, and overall development. Despite this, Pakistan has faced acute energy sector-related crises, and this has led to instances of rampant load-shedding, rising power prices, and a loss of dependence on imported fuels. These structural issues indicate the importance of piloting not only on supply-side constraints but also demand-side factors such as household time-use trends as a potential policy novelty and serve as an intervention point.

Electricity is at the heart of modern home life; it powers all the lights, appliances, and technologies and defines comfort and efficiency, as well as social welfare. The consumption of electricity by the population has increased significantly over the last few decades globally, primarily due to the efforts and urbanization, as well as the use of more electric appliances (Dechamps, 2023; Nie et al., 2024). These new developments are what drive more and more researchers to abandon classical techno-economic outlooks on the usage of electricity. Instead, they are now paying more attention to behavioral and time use trends as major residential energy drivers. It involves this movement on people-centered approaches that lays more focus not just on what energy is used on, but when it is used and how it is used as part of everyday routines, a point which is particularly critical when it comes to the development of countries like Pakistan.

The trend in energy consumption is best understood by organizing the activity patterns on the day-to-day scale. An example is that the peaks in the electric usage are during those periods that some domestic operations run at the normal scheduled moments of the day, say evening hours, when most households are preparing their food or watching TV. Accordingly, along with the models of energy consumption, the behavior of time use can be employed to create a more comprehensive picture of the electricity demand, which might be useful data to policymakers interested in enhancing energy efficiency (Lorincz et al., 2021).

There are a number of factors that affect domestic energy usage, and they are the size of the household, the amount of income, and the presence of energy-saving appliances. Yet, Bagheri et al. (2025) clarify that these new tendencies, including the increasing popularity of smaller household sizes, urbanization, and transition to working remotely, change the conventional consumption patterns. All these changes cumulatively add the effect of a more dynamic energy demand pattern, which could have an important role in energy policy and planning. Household organization in time is a vital component in determining the possible electricity consumption patterns, especially during high periods such as summer. The unique local peaks emerge where the daily regime allows using specific appliances like air conditioning in the afternoon or midday portion, when it is most applicable personally or kitchen use in the evening, when at night energy is most specifically available. Not only are these activities time-bound, which makes them all part of the habits of the summer lifestyles, but studying electricity usage, respectively, requires consideration of amounts, but also time and context. The specific load profiles of appliances also provide an understanding of the contribution of timing of behavioral patterns to aggregate system-wide electricity demand, and can demonstrate how the ability to time specific energy streams can provide strategic, indeed competitive value (Maurya et al., 2023).

It is also being discovered that technological selection and possibilities of engaging behavioral practices have significant impacts on the demand for electricity in the household. Using the case study, Olatunde et al. (2024) explain that purchasing energy-efficient critters is one of the biggest solutions to reducing energy consumption, one of the direct pathways to conservation. However, Nawaz et al. (2022) note that the presence of technology is not enough, as they mention the role of behavioral aspects such as the length of the stay at home, awareness of energy-saving methods, and the daily use of any appliance in the consumption behaviour. Together, these studies imply that simple appliances will be needed, though behavioral participation and awareness are equally essential to the simple appliances when it comes to reducing the consumption of electric energy used in houses.

With the increased integration of urban lifestyles, transportation behavior is increasingly influencing the quantities of electricity used by households. This time, as well as the mode of commute (car, bus, train), directly affects the time that people spend at home, and therefore the time and quantity of electricity consumption. Longer-commuting families will tend to have their usage concentrated during the peak hour as opposed to the shorter commuting or more flexible commuting families, who will generally have a more diffused profile of usage over the day. This way of personalized daily movements being correlated to energy scaling suggests the centrality of time management and routine that greatly impact the residential energy consumption patterns (Acosta-Sequeda et al., 2023; Satre-Meloy et al., 2020).

The issue of electricity in Pakistan is more than the science of generating electricity. Though the increase in power production in the country has been observed lately, poor policy implementation, inefficiencies, absence of infrastructure, and poor demand-side management pose hurdles. The domestic sector is the largest stakeholder, and it uses approximately 48 percent of the total electricity consumed (Gunkel et al., 2023). There is also the issue of regional inequality, where urban families are more likely to have a more uniform supply and a higher consumption rate, whereas rural people are subjected to periodic failures of supply and low grid access. These structural weaknesses, coupled with weak societal awareness and inefficient patterns of utilization, point to the conclusion that more localized and geographically balanced energy policies are needed.

This amount continued to grow with the circular debt becoming Rs. 2.6 trillion by 2024. To safeguard the Chinese-financed IPPs against circular debt, a revolving fund was to be established. But this fund could not fly due to financial limitations. This led to the growth of outstanding receivables of Chinese IPPs from Rs. 230 billion (year 2021) to Rs. 570 billion (year 2024). Such IPPs have been forgiving 53 percent of the government pay, even further degrading their economic status. The IMF was pressurizing Pakistan to end state subsidies and which increased consumer bills without avoiding circular debt. However, such measures ended up raising consumer bills, without rectifying the real cause electricity crisis. Therefore, there was an accumulation of debt, and power sector inefficiencies persisted (Van Der Eng, 2024).

The situation in Pakistan is that the issues of overcoming the trends of consumption within the domestic sector are not just technological and behavioral matters, due to which the electricity consumption patterns can be improved in the domestic sector, but it is also an institutional matter. Despite all the increased power generation capacity, traditional lapses in governance (including in the form of lack of cooperation amongst governing bodies, inconsistency of policy enforcement, and a general lack of responsibility) have conspired to bring the total success ratios of the continued energy demand management programs to their knees. There are still instances of inefficient electricity consumption even with energy conservation campaigns being implemented, and an absence of the integration of behavioral knowledge into the policy-making process (Samad et al., 2024; Lin et al., 2024). These institutional shortfalls should be addressed to help ensure the households have more sustainable and efficient patterns of electricity consumption.

Together with modifications of behavior and technology, energy systems have transformed, and the utilization of the price of time of use (TOU) has become a focus, in line with scheduling electricity consumption with grid performance. Domestic users cannot be considered as simple consumers but instead as drivers who would make more strategic choices when they engage in activities with high energy demands. Recent evidence indicates that not only is the timing of demand for electricity shifting by TOU price, but it is also prompting people to shift to more flexible schedules and smarter regimes of control with a goal of reducing expenditures. The increasing sensitivity to timing information regarding energy is due to the time utilization conduct where significant roles were played in the nerve of the modern electricity demand (Muttaqee et al., 2024; Ghafoor et al., 2024).

The culture and personal values climate sets in, more in telling how Pakistanis think and act about and towards energy saving. In addition to the economic factor, the energy-saving behavior is apt to be driven by environmentalism, social concern, and the normative values disseminated by families and the community. The visualization of the behavior control and moral duty is at the base of the act of turning off the appliances, a decision to reduce consumption, or a choice to purchase energy-efficient devices within most households, instead of focusing on electric bills. Such psychosocial factors establish the need to incorporate behavioral knowledge into the energy policy, particularly in the Pakistani context, where people may contribute significantly toward estimating the impacts of electricity in households by taking part and being educated (Nawaz et al., 2022).

The demographics are excellent predictors of household electric usage, and they provide a low-cost, scalable means of finding out about energy use in the city. Type of residence, income, education, and household size are good variables that make a difference in shaping the patterns of use as surrogates to more general socioeconomic patterns and style of life. The parameters enable simulation of residential electric load and variation in the populated, urban areas, as it is later used in the planning of sustainable energy infrastructures (Ali et al., 2022). Using the provided data on the population of the people, the planners and policymakers are able to better anticipate the extent of the consumption and hence plan the intervention as well as equitabilities in the area of provision of energy, especially in the cities that seem sustainable.

In recent years, energy prices have increased abruptly in Pakistan, resulting in disproportionately high costs to lower- and middle-income individuals. These are sectors in society that are already expenditure a maximum of 9.7 percent of their incomes in the energy sector, and the statistic is against the fact that in most cases in the developed world, the average spending has got to do with 5 percent of their wages. This economic burden not only comes to the domestic budgets with it, but it also aggravates energy poverty and, therefore, it is necessary to provide immediate energy policies that take into account these inequalities (Li et al., 2025). The high cost of power, to most households, comes at the expense of difficult choices, and most households will have to sacrifice when it comes to health, education, and basic consumption, in order to receive the energy. Furthermore, the unequal distribution of energy burden also falls on the poor and rural people, who also have poorer access to low energy costs and secure supplies. The need and demand that will be served by specifically directed policies so as to make energy saving, expand the supplies of renewable energy, and offer subsidies to exposed and poor individuals thus solving this price increment must respond to this price increment by and by augmenting their shares of offering basic energy services to all the citizens on the planet without hampering economic position of these groups (Sattar & Ali, 2024).

Energy access scarcities denote more structural and infrastructural constraints, especially in the more distant and prestigious settings where electrification programme design and physicalization may take longer than usual to realize and have low support. These deficiencies are also compounded by the fact that the country is not performing well on international development indicators. In 2021, the SDGs global index ranked Pakistan at position 129 among 165 nations, and the overall rating was low at 57.7 percent. The position was not only worse than the world average of 65.7 percent but was lower than regional peer comparators in Bangladesh (63.5 percent) and India (60.1 percent) (Sachs et al., 2022). In a bid to make the same a source, there is the aspect of an increase in the cost of production of electricity, primarily due to the fact that the country entirely relies on imported fossil fuel and old generation infrastructure. The increased cost is passed over to the consumers and is repaid through inflated energy bills. Consequently, this spending on energy is sustaining a huge percentage of domestic revenues, particularly in poor and middle-income households. This expenditure has increased the energy-poverty issue, minimizing the purchasing power of households to afford other necessities in the economy, such as education, nutrition, and health (Farrell and Fry, 2021).

Methodology

This study adopts a quantitative, cross-sectional research design to investigate the causal relationship between time-use behavior and residential electricity consumption in Central Punjab, Pakistan. The primary aim is to explore how household routines, appliance usage, and socio-demographic characteristics contribute to electricity demand variations in urban settings.

Study Area and Sampling

Data were collected from a total of 200 households, with 100 households each from Lahore and Faisalabad. These two cities were purposively selected due to their distinct socio-economic, demographic, and infrastructural characteristics. Lahore, a highly urbanized metropolis, presents more modernized residential and energy-use behaviors, while Faisalabad, though industrialized, retains more traditional and frugal consumption practices. This diversity allows for meaningful comparative analysis.

A purposive sampling technique was employed to ensure the inclusion of households with access to electricity and decision-making authority over household energy consumption. Households were further screened based on their willingness to record detailed time-use logs and provide access to electricity bills, which enhanced the reliability of the consumption data.

Data Collection Tools and Procedure

Data were collected using a structured questionnaire administered through face-to-face interviews. The instrument was designed to gather information on:

1. Socio-demographic variables (age, gender, education, household size, income)
2. Appliance ownership and usage patterns
3. Daily activity patterns, collected via a 24-hour recall activity log
4. Perceptions and practices related to energy conservation
5. Electricity consumption, obtained from monthly utility bills, where available

To supplement survey data, time-use logs were maintained by the participants to track hourly household routines and associated electricity-related activities, such as cooking, cleaning, entertainment, and heating/cooling. This approach allowed for a more granular analysis of the link between behavior and consumption.

Analytical Framework

Data analysis was conducted using IBM SPSS for descriptive and comparative statistics, and Stata for econometric modeling. The core analytical technique employed was the Oaxaca–Blinder decomposition model, which is commonly used to decompose group differences in outcomes (in this case, electricity consumption) into "explained" and "unexplained" components.

The mathematical form of the model is given as:

$$\Delta Y = (\bar{x}L - \bar{x}F)\beta + \bar{x}F(\beta L - \beta F) \quad (1)$$

Whereas:

ΔY is the average difference in electricity consumption between Lahore (L) and Faisalabad (F)

$\bar{x}$ denotes the mean characteristics of each group

β denotes the estimated coefficients for each group

The first term on the right-hand side represents the portion of the consumption gap attributable to observable characteristics (explained component), while the second term captures differences due to behavior, preferences, or unobserved factors (unexplained component). This distinction is crucial for understanding whether energy consumption differences are structural or behavioral.

Visual Analytics

In addition to statistical models, Sankey diagrams were developed to provide a visual narrative of how daily time-use patterns are translated into electricity consumption behaviors. These diagrams illustrate the flow of time across different activities (e.g., cooking, working, leisure) and how these activities correspond to appliance usage throughout the day.

The integration of Sankey diagrams with empirical results enables a holistic understanding of energy demand, emphasizing not only what households consume but also when and why electricity is used. This visual tool helps bridge the gap between quantitative metrics and behavioral insights.

Results and Discussion

This presents and interprets the empirical findings derived from the primary data collected in Lahore and Faisalabad to explore the causal relationship between time use behavior and residential electricity consumption. The results are organized to offer both a descriptive overview of household characteristics and appliance usage patterns, as well as a deeper econometric insight into inter-city differences using the Oaxaca decomposition model.

Descriptive Statistics

Demographic Characteristics

Table 1 socio-demographic profile reflects considerable diversity across the sample, which is critical for understanding household electricity consumption patterns. Approximately 38% of respondents were male, highlighting active female involvement in household decision-making regarding energy use. The sample was almost equally distributed between Lahore and Faisalabad, providing insights into both urban and industrial household contexts.

Table 1. Descriptive statistics for socio-demographic characteristics.

Variable Description	M	Mdn	SD
Gender (1 = Male, 0 = Female)	0.38	0.00	0.49
City (1 = Lahore, 2 = Faisalabad)	1.51	2.00	0.50
Marital Status (0–3)	1.52	1.00	0.57
Family Structure (1 = Nuclear, 2 = Joint)	1.42	1.00	0.50
Age Group (1 = <20, ..., 5 = >60)	2.08	2.00	1.27
Occupation Category (1–7)	3.09	3.00	1.97
Education Level (1–6)	3.79	4.00	1.17
Family Size Category (1–5)	2.26	2.00	0.90
Employment Class (1–5)	1.96	2.00	1.05
Income Class (1–5)	2.55	2.00	1.06

Most respondents lived in nuclear families, and the dominant age group was 20–30 years, indicating a relatively young, economically active population. Education levels averaged around intermediate to undergraduate, which has been linked to greater awareness of energy-efficient behaviors (Rahman et al., 2022). Household size, employment class, and income class showed variation, creating a diverse foundation to analyze how socio-demographic factors influence time use behavior and electricity consumption.

Appliance Ownership and Usage Behavior

In Table 2 descriptive statistics reveal significant differences in appliance ownership and electricity use patterns across households. Overall, electricity usage remained moderate (Mean = 1.58), while fans, fridges, and LED bulbs were among the most common and frequently used appliances, consistent with typical energy demand in urban households.

Table 2. Descriptive statistics for appliance ownership and electricity use behaviors (n = 200).

Variable Description	M	Mdn	SD
Electricity Usage Class (1–5)	1.58	1.00	.859
Fan Ownership Class (1–5)	2.10	2.00	0.97
Fan Usage Class (1–5)	2.49	2.00	1.05
No. of Air Conditioners	1.07	1.00	1.26
AC Usage Class (1–5)	2.02	2.00	1.03
No. of Washing Machines	0.99	1.00	0.46
Washing Machine Usage Class (1–5)	2.37	2.00	0.81
LED Bulb Ownership Class (1–5)	1.87	2.00	0.96
LED Usage Class (1–5)	3.40	4.00	1.32
No. of Room Coolers	0.72	1.00	0.78
Cooler Usage Class (1–5)	2.06	2.00	1.18
Fridge Usage Class (1–5)	4.82	5.00	0.54
No. of Fridges	1.11	1.00	0.37
No. of Laptops	1.26	1.00	1.12
Laptop Usage Class (1–5)	2.15	2.00	1.06
No. of Computers	0.24	0.00	0.50
Computer Usage Class (1–5)	1.38	1.00	0.87
No. of Electric Irons	1.20	1.00	0.46

Iron Usage Class (1–5)	1.29	1.00	0.45
No. of Water Motor Pumps	1.09	1.00	0.29
Water Pump Usage Class (1–5)	1.56	1.00	0.86
No. of LCD TVs	1.56	1.00	0.89
LCD Hourly Usage Class (1–5)	2.39	2.00	0.97
No. of Stand Fans	0.66	0.00	0.98
Stand Fan Usage Class (1–5)	2.04	1.00	1.37
Other Electric Appliances Owned (0–5)	2.27	2.00	1.53
Usage of Other Electric Appliances (1–5)	2.29	2.00	0.81
No. of Electricity Meters	1.58	1.00	0.65
Solar Panel Installed (1 = Yes, 0 = No)	0.21	0.00	0.41
Number of Solar Panels (if any)	0.78	0.00	2.42

Ownership of air conditioners was moderate, but usage levels were low, likely reflecting affordability barriers or conscious efforts to reduce consumption. Notably, LED bulb usage was relatively high, indicating positive trends toward energy-efficient lighting (Global Electricity Review, 2024). Essential appliances like washing machines, fridges, and water pumps were widely present, with refrigerators showing particularly high usage levels, reflecting their importance in daily household functioning.

Solar panel adoption remains low at 21%, suggesting limited penetration of renewable energy technologies at the household level, a challenge consistent with national trends. These findings emphasize the need for greater awareness and policy support to encourage energy-efficient technologies and renewable energy adoption in residential settings.

Time Use, Daily Energy Engagement, Awareness and Energy Conscious Practices

Table 3 results reveal significant variation in daily routines, energy awareness, and consumption-related behaviors among the surveyed households. The majority of respondents spent more than 8 hours at home on weekdays, with a mean score of 3.27, highlighting the potential impact of time spent at home on energy demand, a factor increasingly emphasized in recent energy behavior research (Reames et al., 2022).

In response to load shedding, most households relied on backup solutions such as UPS, generators, or solar panels, reflected in the mean backup type score of 3.15, underlining household adaptation to unreliable electricity supply.

Table 3. Descriptive statistics for daily energy engagement, awareness and energy conscious practices (N = 200).

Variable Description	M	Mdn	SD
Weekday Hours Spent at Home (1 = <4 hrs, 4 = >12 hrs)	3.27	4.00	0.95
Load Shedding Backup Type (1–5)	3.15	4.00	1.85
Online Activity Frequency (1–4)	3.16	4.00	1.07
Awareness of Efficient Appliances (1 = Yes, 0 = No)	0.72	1.00	0.45
Replaced Old Appliances (1 = Yes, 0 = No)	0.61	1.00	0.49
Appliance Purchase Factors (1–12)	2.91	2.00	2.76
Frequency of Unplugging Appliances (1 = Never, 5 = Always)	4.24	5.00	1.22
Awareness of Electricity Rates (1–3)	2.43	3.00	0.68
Ease of Understanding Time-of-Use Rates (0–3)	1.97	2.00	1.04
Belief Daily Routine Affects Electricity Use (0 = No, 1 = Yes, 2 = Not Sure)	0.97	1.00	0.56

Encouragingly, awareness of energy-efficient appliances was relatively high (72%) and 61% of households reported replacing old appliances, consistent with global trends toward adopting energy-saving technologies (Ramani et al., 2023). Unplugging practices were frequent (Mean = 4.24), indicating growing energy-conscious behavior among respondents. However, gaps remain in understanding electricity rates and time-of-use pricing, with moderate ease of understanding reported (Mean = 1.97), suggesting the need for improved energy literacy programs (Satre-Meloy, 2019). Importantly, 97% of respondents believed their daily routines influence electricity consumption, reinforcing the critical role of behavior and time use patterns in shaping household energy demand (Rafiq et al., 2023).

Oaxaca-Blinder Decomposition of Electricity Consumption by City

Table 4. Oaxaca-Blinder decomposition results: log monthly electricity by city overall group statistics.

Group	Mean Log Electricity	Std. Error	z	p-value	95% Conf. Interval
City = 0	9.739971	0.0721519	134.99	0.000	9.598555, 9.881386
City = 1	10.21599	0.0660094	154.77	0.000	10.08662, 10.34537
Difference	-0.4760244	0.0977913	-4.87	0.000	-0.6676918, -0.2843569

The Oaxaca-Blinder decomposition results reveal a significant disparity in residential electricity consumption between Lahore and Faisalabad. Table 4 shows mean log of monthly electricity consumption for Faisalabad households (City = 0) was 10.22, compared to 9.74 for Lahore (City = 1), indicating that, on average, Lahore households consume more electricity. The observed difference of -0.476 in log electricity consumption is statistically significant ($p < 0.001$), suggesting substantial variation between the two cities. The gap indicates disparities in household features, possession of appliances, socio-economic status, and time use profile, in line with the recent literature gathering special attention on spatial, behavioural factors being determinants of household energy consumption (Miraki et al., 2025; Reames et al., 2022). These observations make it evident that focusing on the level of the city and household behavior should be taken into account during the creation of aimed energy management and demand-side interventions.

Oaxaca-Blinder Decomposition of Electricity Consumption by City

Table 5. Decomposition of the difference in electricity consumption by city.

Component	Coef.	Std. Err.	Z	p-value	95% Conf. Interval
Endowments	-0.1153465	0.0859464	-1.34	0.180	-0.2837983, 0.0531053
Coefficients	-0.4952848	0.1286919	-3.85	0.000	-0.7475163, -0.2430534
Interaction	0.134607	0.1282281	1.05	0.294	-0.1167154, 0.3859295

The results of decomposition indicate a very pronounced difference between the consumption of electricity used to power residential units in Lahore and Faisalabad. Table 5 shows the log of monthly electricity consumption of Faisalabad (City = 0) and Lahore (City = 1) households. Mean 9.74, Mean 10.22 indicates that, on average, Lahore households consume electricity a lot more than Faisalabad households. Only the total of the observed differences, which was -0.476 (Faisalabad minus Lahore), was statistically significant ($p < 0.001$), with Lahore recording higher consumption levels. Further decomposition of this gap shows that the endowments effect, which reflects differences in observable household characteristics such as income, appliance ownership, and time use patterns, accounts for only -0.115 of the gaps and is not statistically significant ($p = 0.180$). This suggests that differences in measurable household attributes alone do not explain the higher electricity consumption observed in Lahore. In contrast, the coefficients effect, which captures differences in how these characteristics translate into electricity consumption, contributes significantly to the gap (-0.495, $p < 0.001$). This implies that unobservable structural, behavioral, and contextual factors, including variations in daily routines, energy-use habits, efficiency awareness, and city-specific infrastructure, are key drivers of the higher energy consumption in Lahore (Reames et al., 2022). There is a weak effect of interaction, which is statistically insignificant, indicating that the overall effect of characteristics and their impact on electricity consumption is also limited. Such evidences show why efforts to change policy should not be limited to enhancing household characteristics. Rather than specific interventions such as behavioral change, energy efficiency awareness, and infrastructure should be focused in order to tackle electricity consumption inequity in urbanized areas (and specifically in fast-growing cities like Lahore).

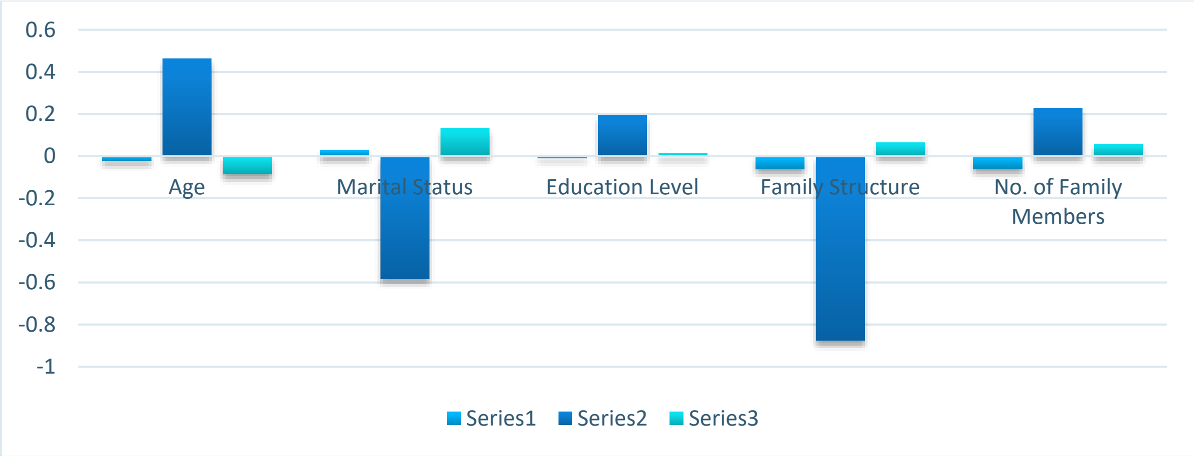

Figure 1. Oaxaca-Blinder Decomposition: Component Effects.

The bar chart describes the contribution of individual socio-demographic variables towards the electricity consumption difference between Lahore and Faisalabad as shown in Figure 1. Our chart has three data series series 1, series 2 and series 3 and these are various estimation models or statistical specifications utilized to study the amount of each factor. The estimates show that Age and Education Level depict a positive contribution, implying that these variables negatively impact on electricity gap between the two cities to some extent. On the contrary, Marital Status and Family Structure have a negative impact, with the greatest impact of Family Structure being negative. This means that the consumption gap is greatly expanded by any variation in household arrangements, e.g., the abundance of joint and nuclear families. Also, there is a very small positive influence displayed in the Number of Family Members, and it means that the task of this variable in reducing the gap is insignificant. The trends are in line with more current research, highlighting that differences in household composition and socio-demographic features, to some degree, influence urban energy usage. However, a considerable portion of the gap remains influenced by behavioral and structural factors beyond observable household traits (Medojevic et al., 2021).

Table 6. Detailed variable contributions to endowments.

Variable	Coef.	Std. Err.	z	p-value	95% Conf. Interval
Age (years)	-0.0216	0.0336	-0.64	0.519	-0.0874, 0.0442
Gender	0.0026	0.0074	0.35	0.727	-0.0119, 0.0171
Marital status	0.0298	0.0423	0.70	0.481	-0.0531, 0.1128
Education level	-0.0082	0.0172	-0.48	0.632	-0.0418, 0.0254
Family structure	-0.0622	0.0422	-1.47	0.141	-0.1450, 0.0206
Number of family members	-0.0608	0.0454	-1.34	0.180	-0.1497, 0.0281
Household monthly income	-0.0058	0.0171	-0.34	0.734	-0.0393, 0.0277
No of fans in the home	0.0019	0.0217	0.09	0.931	-0.0406, 0.0444
No of air conditioner in the home	0.0149	0.0168	0.89	0.376	-0.0181, 0.0479
No of fridges in the home	-0.0002	0.0021	-0.08	0.937	-0.0043, 0.0040
No of washing machine in the home	0.0035	0.0095	0.37	0.711	-0.0151, 0.0222
No of led bulb in the home	0.0041	0.0153	0.27	0.789	-0.0260, 0.0342
No of room cooler in the home	0.0034	0.0081	0.42	0.672	-0.0125, 0.0194
No of stand fan	-0.0176	0.0234	-0.75	0.453	-0.0636, 0.0284
Fans usage of hours per day	0.0021	0.0086	0.24	0.807	-0.0147, 0.0189
Air conditioner usage of hours per day	0.0123	0.0183	0.67	0.503	-0.0236, 0.0481
Fridge usage of hours per day	-0.0008	0.0063	-0.13	0.897	-0.0132, 0.0116
Washing machine usage of hours weekly	-0.0117	0.0173	-0.68	0.497	-0.0455, 0.0221
Led bulb usage of hours per day	0.0066	0.0192	0.34	0.731	-0.0310, 0.0442
Lcd hourly usage per day	-0.0135	0.0149	-0.91	0.364	-0.0426, 0.0156
Stand fan hourly usage per day	0.0059	0.0186	0.32	0.752	-0.0306, 0.0423

The detailed decomposition of the endowment's component provides further insight into how specific household characteristics contribute to the electricity consumption gap between Lahore and Faisalabad. The results in Table 6 indicate that none of the examined variables, including socio-demographic factors, appliance ownership, or usage patterns, significantly explain the consumption gap, as all p-values exceed the 0.05 threshold. Variables such as age, education level, family structure, and number of family members exhibit negative coefficients, suggesting that these characteristics slightly reduce the electricity consumption gap between the two cities. However, these effects are statistically insignificant. Similarly, commonly considered energy-relevant factors like household income, number of fans, air conditioners, refrigerators, washing machines, LED bulbs, room coolers, and their respective usage hours also fail to contribute significantly to explaining the observed gap. These findings highlight that observable household and appliance characteristics alone do not account for the electricity consumption disparity between Lahore and Faisalabad. Instead, the majority of the gap is likely driven by unobservable factors such as behavioral differences, variations in energy-use habits, infrastructure conditions, or differences in awareness levels, which are reflected in the significant coefficients effect observed earlier. These results align with recent studies emphasizing that beyond material conditions, behavioral and contextual factors play a critical role in shaping household energy consumption patterns (Miao et al., 2022).

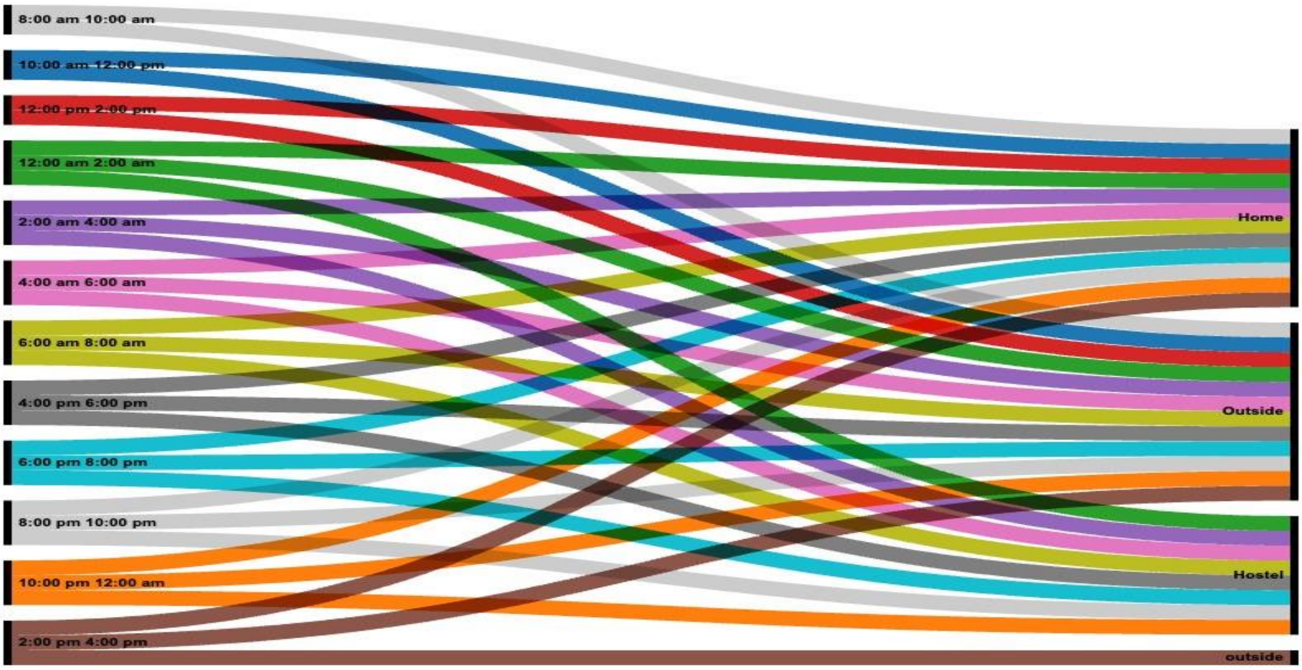

Figure 2. Depicting time use and location patterns of respondents.

This figure 2 captures the movement between key locations, namely Home, Outside and Hostel, offering crucial insights into how time-use patterns translate into spatial mobility, which in turn influences residential electricity consumption patterns. According to the diagram, the early morning hours (12.00 am to 8.00 am) display a significant percentage of people at Home, which justifies resting and family activities at this time. It is interesting to note that the hour range of 2 am to 4 am and 4 am to 6 am records very little activity outdoors, indicating that most members of the household are active within the home setting. This confirms the trends in the preceding diagram of appliance use, where critical appliances like fans, fridges, and air coolers are in continuous use during these hours in order to ensure comfort in a sleep environment.

One of the shifts is marked in the time interval between 6:00 am and 10:00 am, when the graph demonstrates a prominent growth of people who go outside, but there is still a large number of people who are not at Home. Such a period of time is linked to commuting to work (and other professional activities), study, and other external activities. Its gendered connotations are also rather applicable because earlier research (Suomalainen et al., 2019; Yu et al., 2020) indicates that women, constrained by house duties, have a tendency to stay home during these hours, which adds up to the continued use of electricity in the household.

The late morning time between 10. 00 am and 2. 00 pm shows a significant proportion of the people still being outside, reflecting the varied spatial form of cities like Lahore and Faisalabad, where people live at home or at Hostels. This decentralization of presence has direct consequences in regard to electricity consumption. The energy demand during such hours can be lower in households with occupants who reduce the number of occupants during such hours, especially cooling and entertainment devices. Homes in which women are occupants or aged family members staying may, on the other hand, have a prolonged duration of appliance use at increased power. As the day gradually ushers in the afternoon and evening hours (2:00 pm to 8:00 pm), we notice that people find their way back through the diagram, out of their exterior destinations, back home. This time is similar to high residential usage, such as cooking, cooling, entertainment, and family activities, and this fact can also be supported by the above Sankey diagram of appliance usage during these hours. Also, the nature of people in Hostels is indicative of the individual living arrangements without others, generally student/single workers, and thus these patterns can be different enough to have wider implications for energy demand patterns during residential discourse. The late night and evening hours (8:00 pm to 12:00 am) will be noted as another concentration of people at Home, further strengthening the observed surge of energy demand at this time of day in lighting, cooling and entertainment loads. The lack of movement to Outside or Hostels in these hours expresses a shift to rest and indoor activity.

Altogether, this Sankey diagram implies a close connection between time-use behavior, spatial mobility, and household electricity consumption. There is a gendered aspect of this, interestingly enough, because women are more likely to spend the day at home, hence the continued use of domestic appliances. These results are consistent with the evidence on the international level (Yu et al., 2020; Suomalainen et al., 2019) and reaffirm the importance of energy policies with opportunities to take both time and space household dynamics into consideration. Interventions aimed at the promotion of energy-efficient appliances and the conduct of awareness campaigns to address household members, especially women, can become effective in reducing electricity demand without impeding household routines and gender roles.

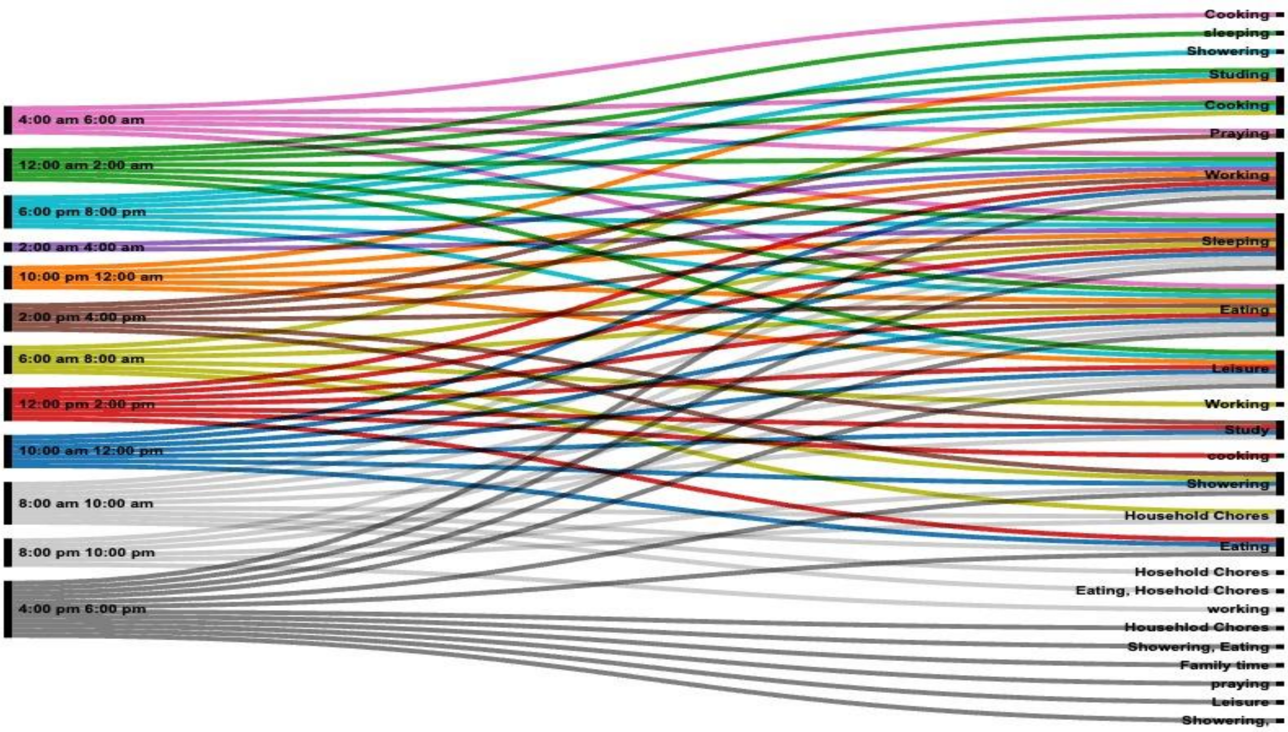

Figure 3. Time-use distribution of respondents by activity across a 24-hour period.

Figure 3 provides a visual profile of household time use behavior encompassing such a variety of activities as sleeping, cooking, working, leisure, studying, showering, praying, household chores, and family time, illustrating the heterogeneity and sexual differences of the time use behavior profile in households.

In the late-night hours (12:00 am to 6:00 am), there is a marked time-allocation to sleeping with just a few numbers of people involved in cooking, showering, studying, and praying. This shows a typical housewife practice of most people at rest and a small proportion, in most cases, women, in traditional societies where preparations and worship may be going on in the early morning. Such prominent cooking, household chores even during these hours are indicative of the gendered time burden women face as reported by Suomalainen et al. (2019) and Yu et al. (2020), focusing on the over representative distribution of unpaid household work among women, and accordingly the division of energy into domestic activities, with a direct effect on household energy-related practices.

As the day goes into the morning hours (6:00 am to 12:00 pm), the graph indicates a drastic rise in working, studying, chores, showering, and eating. These periods indicate the time when there is an onset of productive, home, and self-care operations. The overlapping of working and home duties at the same time can be especially observed in the gender relations analysis since women have to combine paid and unpaid working duties at the same time. Residential electricity consumption is directly affected by this overlap as well, where the combination of working at home, cooking, and home chores may increase the use of appliances and the necessary amount of energy. A heterogeneous format of time use is observed in the afternoon (12:00 pm to 4:00 pm), in which the flows are oriented on work, housework, meals, as well as entertainment. Such an inclusion of leisure in these hours reflects a mixture of paid work, unpaid domestic work, and personal leisure time, a combination that usually varies according to socio-economic status, working system, and gender roles in the home. It is worth noting that persistent participation in housework and cooking in such periods of time supports the claim that time use behavior is one of the major determinants of household electricity consumption, as exhibited in the Chinese empirical article written by Yu et al. (2020).

Evening (4.00 pm to 10.00 pm) is associated with higher attention paid to family, leisure, housework, and food intake, which also represents the overlap of daily family practices, social networking, and domestic duties. The same time happens to be residentially maximal in the usage of electricity in the form of cooking, cooling, entertainment, and lighting within Sankey diagrams illustrating appliance usage and location patterns in the past. There are also gendered implications with this own-time gendered implications with these hours, women usually prepare meals and perform caregiving activities, making their contribution to energy use in the home quite indirect, adding to their share.

Lastly, the late-night range (10:00 pm to 12:00 am) demonstrates the shift back to sleeping and partial involvement in working, fun, and chores. Performance of household chores late at night indicates time poverty of women and caregivers, in line with the international evidence of the unequal use of time, adverse impacts on individual health, and household resource consumption (Suomalainen et al., 2019).

Conclusions and Recommendations

The analysis entails an analytical assessment of the factors behind energy usage in household electricity, with the consideration of both socio-demography and behavioral and time-use patterns of Lahore and Faisalabad households. The descriptive statistics indicate statistically significant deviations in the dimension of the respondent's profile. Household size, appliances, and time spent inside the house were also different, with Lahore taking place over average values in terms of the family income and electricity consumption. Appliance usage patterns differed as well, disclosing the differences in lifestyle, awareness of energy-efficient practices, and daily routine. These findings underscore the importance of behavioral and contextual variables in shaping household energy demand. To further investigate city-level disparities, the Oaxaca-Blinder decomposition was employed. The results indicate a statistically significant gap in the log of monthly electricity consumption between the two cities. Lahore households exhibited higher average consumption compared to Faisalabad. The total observed difference was partially attributed to variations in household characteristics (endowments) such as family size, appliance ownership, and income. However, a significant portion of the gap remained unexplained, suggesting the influence of behavioral or structural factors not fully captured by the included variables. This reinforces the idea that household behavior, beyond observable characteristics, plays a critical role in energy usage.

The Sankey diagrams provide visual insight into respondents' daily rhythms, highlighting the spatial and activity-based distribution of time use. The first Sankey diagram maps individuals' presence across locations, home, outside, and hostel throughout a 24-hour period. The findings indicate that home occupancy is highest during nighttime hours (10:00 pm to 8:00 am), while daytime hours (8:00 am to 6:00 pm) see a substantial shift towards outside engagements. These transitions suggest lower residential energy demand during working hours and heightened demand during periods of home presence. The second Sankey diagram illustrates the allocation of time across specific daily activities such as sleeping, working, studying, cooking, and leisure. Sleeping dominates the late-night and early morning hours, while working and household chores are most prevalent during the day. Energy-intensive tasks such as cooking and showering are spread across multiple time slots, implying recurring electricity use throughout the day. All these behavioral modes correlate well with the peak attributes of energy usage and indicate how daily routine activities control the pattern of energy demand in a household. Together, these results provide strong empirical support for the central hypothesis that time use behavior is a critical determinant of residential electricity consumption. By combining statistical modeling with visual analytics, the study demonstrates that not only physical assets but also temporal and behavioral dynamics must be accounted for when designing energy efficiency interventions or formulating urban energy policy.

To facilitate behavior-based energy conservation, I would work together with NEPRA, DISCOs, media, and NGOs to create specialized awareness programs to focus on the concepts of time-of-use (ToU) awareness, appliance unplugging, and integration of solar energy. Such campaigns ought to be adjusted to various cities and genders, making the most out of local community channels. By promoting the time-responsive wisdom consumption pattern via ToU-driven rewards and SMS notifications, it is possible to shift peak electricity demand to off-peak; gender needs to be injected in both measures, as peak electricity consumption coincides with unpaid care requirements. The gender-inclusive energy interventions also need to be mainstreamed as a policy through offering energy-efficient appliances and labor-saving technologies through microcredit provision to women, improving time poverty, and enhancing the participation of women in making suitable energy decisions in households. The interactivity of bills and the development of Android or iOS applications that allow users to visualize off-peak consumption and discover the opportunities for cost-saving can be employed to enhance transparency in electricity pricing. Finally, the institutionalization of periodical surveys will incorporate time-use information into energy planning to facilitate behavior-responsive forecasting, urban electricity models, and targeted interventions in urban clusters like Lahore and Faisalabad.

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