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Estimating The Socioeconomic Factors Associated With Carbon Emissions at The Household Level For a Sustainable Future In Pakistan. A Case Study of Urban And Peri-Urban Areas of Faisalabad

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Ever-accelerated urbanization and climate change pose significant challenges for sustainability especially in Pakistan. This study examines the social and economic features associated with the emission of CO2 from the household sector in Pakistan. This research concept constructed on the questionnaire and interview-based survey of 280 household respondents from seven major urban and peri-urban areas to estimate carbon emission from residential consumption from Faisalabad city of Pakistan in 2024 through conducting a survey and for carbon metric tons calculation, the web-leading calculator for carbon emission has been used. Carbon emissions in urban areas from the primary sources of household are 0.99 metric tons in urban areas and 0.23 metric tons in peri urban from electricity, Gas, and oil burning, 3.29 and 3.10 from transport carbon emissions respectively in urban and peri-urban areas. Secondary Carbon emission sources contribute 2.520 metric tons in urban areas and 2.02 in other areas. These results indicate that socio-economic features (Income, house size, family size, and electricity bills) are the main contributors as Overall carbon emission is 3.98 metric tons from urban areas and 3.28 in peri urban area that represents 2/3 of carbon emission in the atmosphere, showing the scarcity of low carbon emission policies in the city. These verdicts highlight emission of carbon due to household's activties poses serious challenges in achieving the SDGs goals for the green economy and society. Formulating custom-made strategies for areas and household usage is compulsory to minimize the issue and accomplish towards sustainable future for Pakistan.

Keywords: environmental sustainability, Carbon emission, socioeconomic factors, sustainable future

Global climate changes happen due to Excessive Population growth and urbanization. Pakistan remains among the top nations on the climate change vulnerability index. Pakistan emitted 185.5 million tons of CO2 in 2015 as compared to 2008 the emission was 147.8 million tons (Shaikh, 2015). At present Pakistan's carbon, emission is increasing and stands at 428.6 million tons, CO2 is the Major contributor to is emission of greenhouse gasses (GHG) (Chandrasekhar, 2023). According to Qamar, uz Zaman in Pakistan's climate change policy, (Mustafa, 2015)estimation has gone wrong as Carbon emissions will reach 400 million of tons if the circumstances remain the same by the end of 2030 but current surveys report that this ceiling situation has been achieved in 2023 (Chandrasekhar, 2023). The household contribution to carbon emission is a substantial issue around the world but Pakistan ranks less developed country where climate change was not a significant issue before a couple of years ago. Now this issue is gaining popularity due to mass urbanization, increased industrialization, income per capita, better living standards, family size and use of home appliances and technology, and innovation in consumption forms of fuels, electricity, and gas these are responsible factors for carbo emission from the household sector. Population growth is always the center of issues in fewer countries that increase the use of domestic vehicles and energy demand ultimately transport volume increases. Amount of Carbon emission differ from area to area and household to household. It depends on the usage of consumption categories as directly related to electricity, fuel and transportation (Khan, 2017). After a careful review of the literature. We can categorize the consumption patterns of households into different categories.
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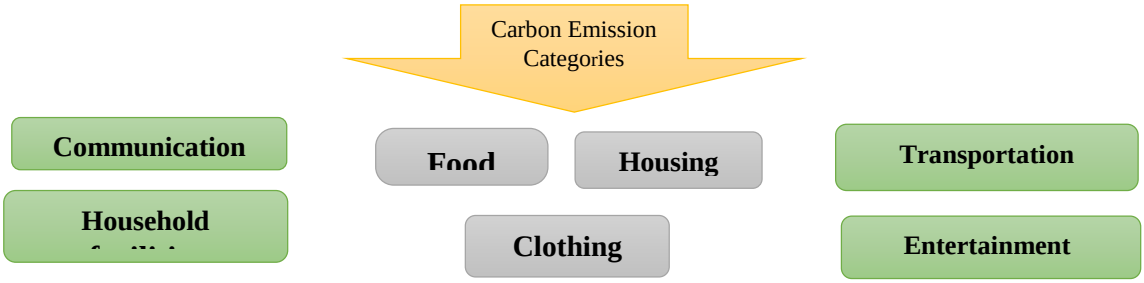
The residential final consumption can be categorized as:



Carbon dioxide CO2, Methane CH4, and Nitrous Oxide N2O are three major and most emit gasses in the atmosphere that are the main reason behind climate change and global warming other are Sulfur hexafluoride SF6 and Tropospheric ozone O3, CCL2F2, CCI2F2 (Shahbaz, 2014). These gasses hold the heat near to earth's atmosphere for a long time that why serious concern arises for global warming.

This paper draws the understanding of carbon emission prediction through pattern of consumption of diverse areas of Faisalabad. Faisalabad is 3rd largest city in Pakistan with the population of 10.6% contribution to the total population of Pakistan (District, 2023). UNO introduced the agency to combat and estimate carbon emissions on the state level but residents of Faisalabad are uninformed of the situation of carbon emissions and their dangerous effects the on atmosphere as well as the economy and society to align with SDGs goals namely SDG 11 (Sustainable cities and communities), SDGs 13 (Climate action). The Exploration of the socioeconomic determinants of household carbon emissions can inform the development of policy interventions that encourage energy efficiency, urban emissions mitigation, and climate resilience in urban and peri-urban Pakistan (Masood et al., 2022). Today people dos not pay proper attention to the environmental degradation but in future the most affected part of the sector is household. Directly the urbanization is epicenter of the carbon emissions and indirectly the generation of electricity through fuels and gasses for domestic purpose in Pakistan is a high contributor to carbon emission

The most important objective of the research is to provide assistance through data and findings that plays a significant role in coping the climate change. In order to provide a better living environment and achieve low carbon society, this study provide a customized pathway for residential areas of Faisalabad, Pakistan, and an over for the other communities.

First, limited focus on household emissions of carbon in developing countries. Ignoring the content and features affecting the carbon emission through households in less developed countries including Pakistan. Third largest city always neglected and there is lack of proper study on emission from household level. That is why a proper survey through questionnaire is conducted in order to cope this problem.
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Neglecting the level of Emission, Previous studies considerate the state-level effect of carbon emission on the economy but ignore the consumption-oriented society and the consumption pattern of households at every level. There is a lack of literature and research studies that identify the presence of carbon emissions.

Transport only considers the factor that affects the carbon emission and the only factor, which contributes to emissions. Other economic and societal circumstances do not take into attention. Previous literature mentioned that transport and domestic vehicles have a direct relation but income of the household, family size, age, and literacy rate, do not consider in calculating factors. Now this study take a step towards the households features and estimate the carbon emission.

Lack of knowledge of low carbon society is also a major flaw because developing countries society are inadequate in gaining knowledge about new terminology and danger. They are unaware of the consequences of carbon emissions and flop to explore the effect over the period on health, education, food, transportation, and future prospects. Lack of government consistent policies and cooperation, in some research where government agencies are involved and foreign funds are available to these researchers but there is a need of the hour that more detailed and customized research and campaigns will organize in the society for the households in lecturing the carbon emission.

This study is addressing economic and societal problem of carbon emission in developing countries in general and specifically within the borders of Pakistan cities. The inevitability, strong relevance and in depth analysis provide the

way to achieve the green economy and communities. This paper focuses the flaws that governments and agencies working on the green economy generally ignore the basic sector of society because, with households, they cannot fully achieve their goals of the green economy in developing countries. This study weighs on the low carbon society complements the relevance and importance.

This study through its findings and analysis provides the highlights for agencies, states, and other international organizations to achieve the goals of sustainable development. A depth analysis, delivers the expected consequences and the effectiveness of policies to cope the carbon emissions at household level. This research is custom made and easily implemented into society to slow down the carbon emission and guaranteeing the sustainable future for Pakistan and other developing countries in the region. Green future can be easily predicting by estimating carbon emission, household consumption pattern, scientific knowledge and benefit of low carbon society at household level. This study is impactful in addressing this issue and contributes in making the green economy and society.

There is limited studies and research available on the concept of carbon emission by household in developing countries especially in Pakistan, this study intends to bridge the gap through examining household Carbon emission in Faisalabad, Pakistan, which is the 3rd largest city by population in Pakistan and 2nd largest in the eastern areas of the region (District, 2023). This area is affected in winter through smoke and in summer, hot weather is taking the lives of the people. The study highlights the socioeconomic factors that exaggerate this issue and adversely affect the society due to per capita income, consumption pattern, domestic usage of vehicles, Electricity fuel and gas usage. In short, these factors are the hazard to sustainable future of the society.

This study highlights the answers the following relatable questions at household level:
Given the limited research and studies on the phenomenon of child labor in Arab societies, the current study aims to fill this gap by examining child labor in Egyptian society, which is one of the prominent Arab societies where this issue is widespread. Taking a socioeconomic perspective, the study recognizes child labor as a challenging social condition that harshly affects many Arab children due to poverty, hunger, deprivation, and family breakdown, thereby posing a threat to Egypt's sustainable future. In light of this, the study seeks to answer the following question:
Q. How, and why do the features of socioeconomic income per household, literacy rate (Education level), Age, size of the family, Consumption pattern of Electricity, Gas, and Fuels reason to affect the Carbon Emission?
In a developing society like Pakistan, The typical phase of this study creates a Customized base of detailed analysis and investigates the economic and societal connection to Carbon emissions. This study will do significant scientific support and compromise valued visions, ensuring the base for research in this field.

Under this study, the innovative part is as follows: Mainly focus on household communities in particular areas of cities. This paper bridges the gap in this field of research by investigating household carbon emissions inevitability, strong relevance, and in-depth analysis provide the way to achieve a green economy and communities.

Literature Review

Carbon emission has been a dangerous and longstanding issue in Developing countries like Pakistan, but from last decade, it has seen a surge in its occurrence because of the economic crisis of the country. For example, Khan (Khan, 2017) highlighted that residential consumption of electricity, automobile combustion, fuel used for cooking, and heating caused for high rate of GHG emission in the air in the Lahore city of Pakistan. Huiyu (Huiyu, 2019) referred to the factors to affect carbon emissions and reduce the emission, Household consumption patterns, and emissions in urban and rural areas of Beijing based on income level, habits of people regarding spending, access to infrastructure, and availability of services. Ottelin (Ottelin, 2019)investigates the effects of urbanization on household's carbon footprints in European cities where 7 percent is less emission of carbon than rural areas in Europe as income and household features are the base of study. Wang (Wang, 2018) refers economic growth expansion leads to urbanization, increase in energy consumption and carbon emission. Various stages of development proposed the demand for transportation and growth in the industrial sector, advancement in technology coupled with growth lead and carbon economy. Miao (Miao, 2017)emphasis the overall carbon emission and energy demands due to the complexity of urban residential energy consumption patterns. The primary indicators of energy consumption trends and carbon emission is affecting from size of households, income, building and lifestyle of the people in China. Moreover states that development, infrastructure, and need for energy, and governmental policies are the main indicators of consumption patterns of energy and Carbon emission. Verma (Verma, 2021) investigates the measures that adopted to offset the negative impacts of urban areas life and their consequences on environmental understanding. Easy access to energy for urban families uses equipment that is energy intensive, heating systems in winter and insulation systems, domestic automobiles. These elements are considering cause root at world platforms for energy consumption and carbon emission.

(IEA 2019) reports emphasize the difference between high income and low-income households within the cities. This reports states that urbanization and income of the households are the linked with carbon emission because more income leads the migration to the more developed areas and demands more energy intensive consumptions, transportation. The per capita carbon emission of households in urban areas are greater than the rural areas. In urban areas, the energy mix societies based on fuels that affect sustainability through air pollution and climate change. Wiedenhofer (Wiedenhofer, 2017) mentions the carbon emission differences in Chinese household according to income level consumption pattern and sustainable development. Basic arguments show that families with more income use goods and services resulting the more carbon emissions. Urban middle class and rich people in emerging nations like China has more carbon emission society due to its economic development and growth as 5% households population results the 19% carbon emission as 1.7 tons carbon emission is calculating in urban rich areas and 0.5 to 1.6 tons in rural areas where income is low. Minh (Minh, 2023) discusses the EKC (environmental Kuznets curve) that the degradation ithe n environment increases due to expansion in the economy and drops particular income levels. The Carbon emission has strong connection with economic growth, renewable energy uses, Smart FDI (Foreign Direct Investment). Income level and FDI can mitigate the consequences of Carbon emission. Renewable energy, clean technology can promote the long-term economic development to achieve the sustainable future under the Paris Agreement.

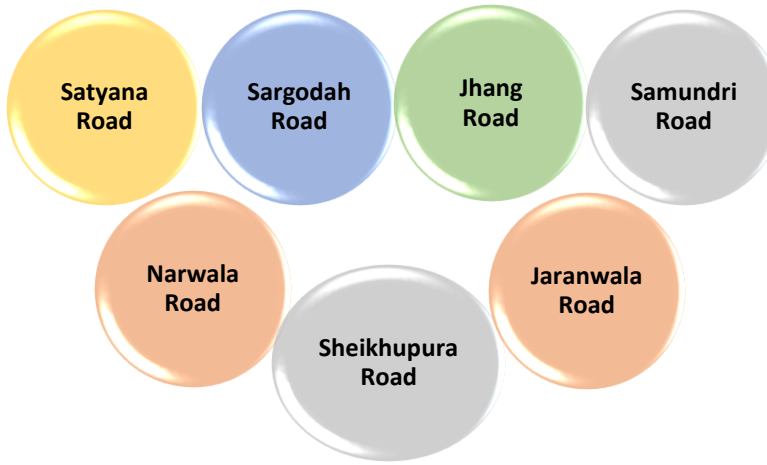
Carbon footprints theory: This theory highlights direct and indirect carbon emission caused through anthropogenic activities, which includes the consumption pattern of households, means of transportation and use of energy. Carbon footprints theory focuses a roadmap for measuring the carbon emissions from individuals or groups and examining various attitudes contribute to total emission (Ivanova, 2016). . The development of a detailed methodology for calculating the direct and indirect carbon emission at every level including household, society, regional, and international levels.

This study investigates the household's carbon emission through primary and secondary sources (Food, Domestic vehicles, etc) in urban and peri-urban areas that are directly related to carbon footprints theory. The implication of this theory at the household level on consumption patterns verdict that the wealthy households are more sensitive to having larger emissions of carbon which helps in explaining the emission from urban and peri-urban in this study.

Sociotechnical transition Theory: This theory gives attention to the transition phase based on technological regime especially high carbon to low carbon regime. This study follows the path of urban and peri-urban household's sociotechnical changes how these areas has sociotechnical transition of low carbon emission. Environmental Kuznets curve: EKC (Environmental Kuznet curve) presents the hypothesis degradation of the environment as carbon emission accelerates the economic development to a certain point and then starts to deteriorate economies' transition to further sustainable practices. This study aligns with EKC, it help so investigate the income level of urban and peri-urban households income level households.

Method

The research area consists of all the seven major roads of urban and peri-urban areas of the third largest city of Pakistan. The total number of households living in this area estimated about according to the records of the Pakistan Bureau of Statistics. The selection of this area for study within the Pakistani society based on the following reasons. These seven major roads are almost cover the whole area and considered the high household density. This factor proves them accurate for studying carbon emission because the more number of households are facing the more carbon emission.



These major seven road areas are diverse regions within Pakistan. By opting for this area, the researcher has to capture a bigger representation of Pakistani society. The selected areas show the undeniable observation of carbon emission due to increased growth in industry and population. This visible presence permits precise and accurate calculation of carbon emissions in Pakistan. These seven major roads provide the opportunity for data collection and availability due to high concentration of households around Faisalabad, Pakistan. This provided the records of estimated number of households resident in areas that facilitated in understating the gage of the problem and formatting the sample size for this research.

The sample size was calculated on behalf of the study community using as shown in Eq. 1 (Loru, 2020) used the confidence interval of 95 % and significance level of 5% in this study

$$n = \frac{N}{1 + N(e)2} \dots\dots\dots\dots\dots$$

Kothari (Kothari, 2004) discussed in detail the result can use from the sample to generalize about the whole population until it actually represented. This study used a sample of respondents from each urban and peri-urban area from seven major roads. This study obtained a sample of 280 respondents who participated in a collection.

Whereas n is the sample size to be studied, N is the number of household respondents or Population size and e is the margin of error in the study.

$$n = \frac{280}{1 + 280(0.05)2} = 164\ households$$

The researchers can choose the respondents according to the judgment that all are provided with the necessary and desired information. The researchers can obtain a 164 respondent sample size from the total targeted population dealing with carbon emissions. The study used multistage sampling because it can easily administrable than other single-stage sampling designs plus the vast quantity of components can be sampled for a given cost because of chronological clustering where which is not feasible in other sampling designs (Kothari, 2004).

Carbon emission The IPCC (IPCC, 2006) provided the base for a methodological approach to calculate the inventories of carbon emissions, now accepted worldwide. Carbon emission factors are projected by multiplying performed activity data (consumption partners of energy, cooling, heating (Electricity bills) with equivalent emission dynamics. This study used default carbon emission factors introduced by IPC. From all sources, carbon emissions are given under (Eq. 1)

$$Ei = \sum A \times \mathrm{EF} \qquad (Eq.1)$$

It should be that Ei is the given carbon emission from all the sources: A is the activity performed data that emits the carbon, and EF is the carbon emission factor of the given gas, oil, electricity category from its source. This equation used to estimate households carbon footprints, specifically applied during collection of data from households. It provides

a method to assess these emissions of urban and peri urban areas editing comparing with in different socioeconomic features.

Table 1

Age and Education of participating Household respondents (Respondents=280)

Variables	statement	Mean	S.D
Age	Urban, 16 to 70 years	34.6	12.5
	Peri-Urban, 15 to 76 years	39.2	13.5
	Overall, 15 to 76 years	36.9	13.5
Education	Urban, up to PhD	10.59	5.8
	Peri-Urban, up to Masters	7.30	5.3
	Overall, upto PhD	8.94	5.4

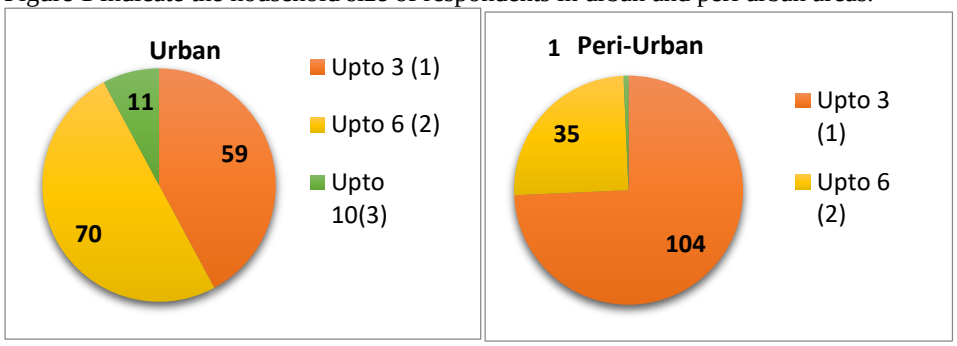
Note* Data in Table 1, the mean value of the number of respondents within each group for the respective variables. The stranded deviation represents that how much or proportion of the respondents data distribute around the mean.

Age and Education Factors: Table 1 shows that carbon emission at high in middle age group because of high mobility and use of energy. This partner suggest the strong association between age and education needing targeted mitigation strategies. This study explains the age of the respondents in urban areas are between 16 to 70 years of old, and the mean value (34.6) represent the wide variety of life stages with S.D (12.5) showing moderate means carbon emission tends to peak in middle age due to lifestyle choices and mobility in urban area. In Peri-Urban areas, data represents that emission increases with age, at peak in middle age due to high economic and social activities and consumption patterns. Overall data suggests that carbon emissions at its peak in middle age of the respondents because of lots of travel related to work and diverse consumption patterns. The significance of the education mean value (10.59) and S.D value 5.8 represent the respondents' must complete the secondary level of education and variability of education level respectively. Higher education leads to sustainability and low per capita carbon emissions because of more maintainable practices in lifestyle and consumption choices. In peri-urban, education is somehow secondary level as mean value (7.30) and SD (5.3) but not leading to intensive higher education. Overall the mean (8.94) of the education group, advises a lack of awareness and sustainability practices irrespective of education up to PhD tends to complex carbon emission.

Figure 1

Respondent's household size Square feet (Marla in Pakistan)

Figure 1 indicate the household size of respondents in urban and peri urban areas.

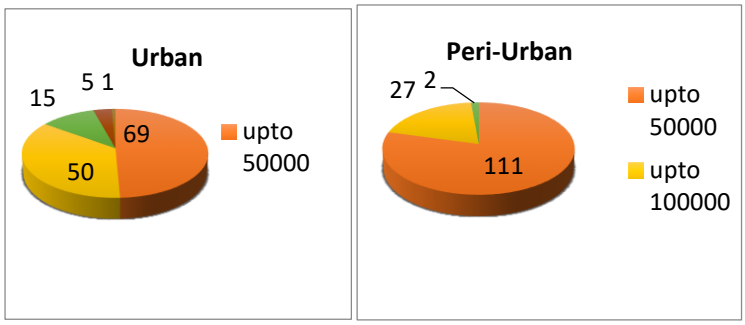


Note* Data in Figure 1 shows the house size of the respondents according to Pakistani society basic local unit Marla (one Marla = Square feet).

House size Factor: Figure 1 shows that smaller households in peri urban areas lead to lower carbon emission because they do not usually need higher energy for consumption and emission still low (Ahmed et al 2021) . This study examines the higher concentration of smaller houses 74.3% of households in 3 Marlas (~ 816 square feet) in peri-urban areas tends to have low carbon emission as compared to urban areas 42.1% of households. Larger houses available in urban areas 50 % and 7.9% of households in up to 6 and 10 Marlas (~ 1632 & 2720 square feet) require more energy for heating, cooling, Lighting, and electricity bills than peri-urban households 25% and 0.7% in same square feet.

Figure 2

Respondent's household income (PKR)



Note*Figure 3 shows the monthly income category of the household respondents in both areas.
(One USD = 276 PKR)

Income Factor: The income distribution diversification is more in urban areas as a higher portion of earnings is between 100,000 and 300,000 PKR (400 to 1200 USD) and have access to more energy-intensive goods such as home appliances and vehicles while in Peri-urban areas most of the households earn upto 50,000 PKR (250 USD). Higher income leads to energy-intensive consumption and carbon emission significantly is higher in urban areas. Hassan and Raza (2023) evident that households with high income per capita demand luxury goods (household appliences demand shown in table 6) for use which leads to more energy usage so that high income households cause to emit more emission. Before jumping into the survey, the household respondents were mature enough, participated voluntarily in the interview, and answered the questions. This study follows all ethical and international known guidelines and pertinent professional principles. The researcher certified compliance with all relevant rules and regulations to keep the confidentiality of the respondent's information.

Interviews: The interviews designed and conducted after a discussion based on a study sample consisting of households in both urban and peri-urban areas. The objective of the interviews was to categorize the socioeconomic features of households that emit carbon to the environment. In addition, the interviews are expected to overview the social and economic challenges tackled by households with direct requirements that need immediate consideration.
The researcher prepared the research questionnaire in order to facilitate the interviews. The questionnaires and interviews consisted of appropriate questions and phrases and the process kept simple, and translated in the local language in time of need. Theoretical and empirical frameworks from the literature review provided the base for the interview questionnaire structure. The data is collected specifically based on equation 1. The relevance and rationality of the interview questionnaires confirmed through these steps:

a. Interview questionnaire rationality/Validity: The pretesting technique used: The preliminary form of questionnaires presented to 20 members of the teaching and research team specialized in environmental economics, climate change, and energy economics from different universities. The experts suggest recommendations and responses after their review and evaluation. The interview questionnaires adapted and unified the expert's suggestions to its final stage. The updated version of the questionnaire included 32 phrases intended to discourse the primary research questions of the study.
b. Field survey:

Observation: The simple observation tools apply to note and observe the appearances and activities of the households. This included the household conditions in which respondents have been residents and their lifestyle. The seven major roads (Jaranwala Road, Sargodha Road, Narwala Road, Satyana Road, samanduri Road, Jhang Road, Sheikhupura Road) of Faisalabad city in Pakistan.

Time: The research conducted within the time limit from January 2023 to September 2024.The respondents of the research were from selected areas of seven major roads that met the benchmark for the proposed sample.
Statistics analysis: Data collection included managing the questionnaire interview of 280 respondents and these conducted by using equation 1 for carbon emission. Each statement of respondents' answers from questionnaires can determined through the Likert scale. This scale used to measure the field survey respondents' motives, opinions, and attitudes related to each phrase or statement in the questionnaires. The study used the statistical software for data sciences (STATA) to fulfill the statistical analysis need. The data examined and construed by applying various statistical coefficients containing frequencies, mean, and stranded deviation. The accuracy of the model is achieved through the implication of statistical criteria as the rationality of the least square assumption is satisfied, the higher the value of adjusted R square, the lower the standard error value practically, and T statistics, and F statistics values are significant.

Results and Discussion

Distribution of household's carbon emission sources: This has been admitted fact that Carbon emission is the aftermath of human activities such as the burning of fuels, usage of vehicles, industrialization, and urban activities. The basic forms of carbon emission due to housing activities (electricity, gas), Transport (cars, bikes, buses), and secondary sources (Food, clothing, entertainment). The primary sources considered such as household consumption patterns of electricity, heating, and cooling from natural gas, and home appliances while transport is also another major contributor to carbon emission. The lack of public transport infrastructure and undue domestic use of fuel-based cars, bikes, and buses provide significant amounts of carbon emissions. Food consumption and production, clothing, and leisure activities includes the secondary source of emission in lifestyle. These activities somehow directly or indirectly challenge sustainable future growth and development in urban areas. This data is collected by using web leading carbon footprint calculation.

Table 2

Sources for a Households carbon emission (Metric Ton/M) in urban and peri urban areas

Sources	Urban (Metric Ton/Month)			Peri-Urban (Metric Ton/Month)		
	Max	Min (S.D)	Mean	Max	Min (S.D)	Mean
Primary (household Electricity, Gas, etc)	0.03	0.1296 (0.17)	0.99	0.02	0.0782 (0.06)	0.23
Transport (Cars, Bikes, Buses, Planes, etc)	0.02	0.8354 (1.1)	3.29	0.02	0.3769 (0.58)	3.10
Secondary (household Food, clothing)	0.016	0.8251 (0.83)	2.52	0.09	0.9805 (0.57)	2.02
Total (other factors)	0.26	1.7864 (1.1)	3.98	0.17	1.4232 (0.74)	3.28

Note* the data in table 2, Minimum (Min): the minimum represents the minimum quantity in a set of data. The data specifies the lowest emission of carbon per month documented for every source in urban and peri-urban areas. Mean:

This is normally a representation of the average carbon emission per month from the mentioned sources. Standard deviation: S.D. suggests how the carbon emission data is varied and consistent. The low value of S.D. indicates similar carbon emissions among households though High S.D. reflects the emission levels among households vary. Maximum (Max): This column refers to the highest quantity in the data set. The Max is the maximum-recorded carbon emission value for every source in urban and peri-urban areas.

Table 2 indicates the amount of carbon emission related to households from three different sources in areas which is calculated by using web leading calculator. The monthly carbon emission from a household's primary source is 0.1296 metric tons in urban areas as compared to 0.0782 metric tons emission in peri-urban areas, because of lifestyle choices and easy access to energy-intensive infrastructure. Urban area's emission is approximately 0.8354 metric tons per month as 0.3769 metric tons per month in peri-urban areas. Under these conditions, total carbon emission is 3.98 metric tons per month for 140 respondents from urban areas in Faisalabad society while 3.28 metric tons of total emission recorded from the same number of respondents in peri-urban areas.

Distribution of household's Carbon emission category:

This study investigates households from their carbon emission because it is important for socioeconomic planning and a sustainable future. This information supports making active, targeted, and justifiable steps to cope with carbon emissions in society. The signatory countries of the Paris Agreement identify the household's carbon emission categories as the primary objective to reduce global warming below 2^{0}C through evaluation and observation.

Table 3

Categories of carbon emission households per month in urban and peri-urban areas

Categories (Emissions Metric tons)	Urban		Peri-Urban		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0 - 1 Metric tons	44	15.5	38	13.5	82	29.00
1 - 2 Metric tons	49	17.5	61	22.0	118	39.5
2 – 3 Metric tons	19	7.0	37	13.0	56	20.0
3 + Metric tons	28	10.0	4	1.5	32	11.5
Total	140	50.0	140	50.0	280	100.0

Note* The data in Table 3, Frequency: Frequency helps specify households participate in the category of carbon emission with the perfect picture of emission distribution among different groups. Percentage: % percentage shows the

extensiveness and rigor of the data within the population. Percentage presents the proportion of households that fall under each category compared to the whole sample size, regularized frequency data within peri-urban and urban areas. Total: The overall sample size from urban is 140 households and 140 sample size from peri-urban areas which combines the total number is 280 households. Table 3 data shows 29% of overall households fall under the 0 -1 level, 39.5% of households come within the 1 -2 category, the 2-3 level has 20 % of households, and 11% under the 3 plus category. The 1- 2 metric tons category is the largest group in this study due to transportation in peri-urban areas and energy-induced consumption in urban areas.

Table 3 identifies categories of carbon emissions into four levels (0-1, 1-2, 2-3, and 3 plus metric tons per month) in urban and peri-urban areas. Observation has been recorded that 15.5% of urban households and 13.5% of peri-urban households fall between 0-1metric ton per month of carbon emission. This level represents that households opt for less energy-intensive life choices, awareness of sustainable society, and less energy-induced consumption patterns. Households fall into the category of 1-2 metric tons monthly representing 39.50 of the total sample 22% from peri-urban areas and 17.5% households from urban areas. This largest group is considered to be a moderate energy group because of its energy consumption patterns, usage of own and public vehicles on long communal routes, and energy needs for houses. The high consumption of transport, energy-induced houses, and large family size are the reasons for the category that 7% of urban households and 13% of peri-urban households under 2-3 metric tons per month of carbon emission. The 3 plus category reflects less share of emissions in urban (10%) and peri-urban (1.3%) households because high use of energy in terms of consumption, transport, and manufacturing.

Socio-economic Household Characteristics with Carbon Emission in urban areas: The climax is that all the respondents in the sample study highlight numerous significance positive and negative consequences subsequent to the carbon emission shown in Table 4. The study represents the analysis of carbon emission and household socioeconomic variables (House size, family size, income, and electricity bills) in urban areas. This analysis demonstrates a major relationship that delivers a vision of how these variables contribute to carbon emissions.

Table 4

Household characteristics family Size, House size, and income and electricity bills with carbon emission in urban areas

Variables	Carbon Emission	Family Size	House size	Income	Electricity Bills
Carbon Emission	**1**				
Family Size	r=0.1299 p=0.1261	**1**			
House Size	r=0.2898 p=0.005	r=0.059 p=0.486	**1**		
Income	r= 0.318 p=0.001	r=0.335 p=0.695	(r=0.365) (p=0.00)	**1**	
Electricity Bills	r=0.380 p=.000	r=0.335 p=0.019	r=0.443 p=0.000	r=0.362 p=0.000	**1**

Table 4 shows the correlation among different household socioeconomic factors focus on family size, house size, household income and electricity bills as indicated Pearson correlation coefficient (r) and corresponding p-value (p). Every value in table presents the strength and significance of the relationship among variables

Table 4, the very first result attained is weak and statistically not significant, showing the relationship between carbon emission and family size as r = 0.1299, p = 0.1261. Families in Urban areas of Faisalabad city have more education level, awareness of low carbon society, and standardized use of energy households that's why results attained in this study show that big families do not play a decisive role in carbon emission determination. Big-area house needs more energy for cooling, lighting, and heating in urban areas resulting in higher carbon emissions. The data shows positive results of carbon emission and house size that is moderate and significant statistically as such r = 0.2898, p = 0.005. Carbon emission and income per capita variables show the result of significance r = 0.318, p = 0.001. In urban areas, there are more employment opportunities, bigger homes, more house appliances and the use of energy-intensive goods, energy-intensive consumption pattern contributes the higher emissions. In urban areas, this study shows the strong relationship between carbon emissions and electricity bills. The values of r = 0.380 and p = 0.000 represent the major indicators of carbon emission in urban areas households. The amount of electricity bills shows the consumption of energy in households so bills mostly are on the higher side in urban areas.

Socio-economic Household Characteristics with Carbon Emission in Peri-urban Areas:

This part of the study represents the relationship between carbon emission and household socio-economic variables (House size, family size, income, and electricity bills) in peri-urban areas.

Table 5

Household characteristic family size, House size, income and electricity with carbon emission in peri-urban areas

Variables	Carbon Emission	Family Size	House size	Income	Electricity Bills
Carbon Emission	**1**				
Family Size	r=0.335 p=0.000	**1**			
House Size	r=0.378 p=.000	r=0.354 p=.000	**1**		
Income	r=0.346 p=.000	r=0.389 p=.000	r=0.303 p=.003	**1**	
Electricity Bills	r=0.112 p=.187	r=0.206 p=.014	r=0.049 p=.557	r=0.257 p=.021	**1**

the data in Table 5. Pearson correlation coefficient: r is the quantity that measures the direction and strength of a linear relationship between two variables ranging from -1 to +1. This shows how much the intensity of the relationship among variables such as family size, house size, income, and electricity is correlated with carbon emission. p-value shows the indication that the correlation is significant statistically. These value demonstrations in the study validate that the relationship or quantity observed from r that occurs is by chance or is meaningful statistically. p-value threshold is often used 0.05 as a $p < 0.05$ this result is considered statistically significant alternatively $p \geq 0.05$ this result is statistically not meaningful.

Table 5, the study shows that family size has a positive relationship with carbon emissions in peri-urban areas due to long routes, conventional means of transportation and energy-intensive home appliances, and traditional energy consumption partners in big families. The r = 0.335 and p = 0.000 suggest that large family size has a positive impact and is statistically significant for carbon emission. In peri-urban areas, the vertical houses societies are mostly in trend, more population and expanded house size have shown strong and meaningful relationships on carbon emission as r = 0.378 and p = 0.000. Households with a high income ratio invest in energy-intensive goods and services as buying private vehicles and home appliances which shows a positive and significant effect on carbon emission as r = 0.346 and p = 0.000. Shockingly, the electricity bills in peri-urban areas represent a weak and not meaningful impact on carbon emission due to the use of primary and traditional means of energy sources. Households in these areas mostly not rely on electricity because they used to burn the wood for heating and making food. Therefore, there is a weak and statistically insignificant relationship r = 0.112, p = 0.187 in this study.

Table 6

Household energy intensive appliances in urban and peri urban areas

Items	Urban			Peri-Urban		
	Min	Mean (SD)	Max	Min	Mean (SD)	Max
Fridge /Freezer	1	1.22 (0.47)	3	0	0.89 (0.46)	3
Air Conditioner	0	1.09 (1.04)	6	0	0.19 (0.48)	3
Ovens	0	0.95 (0.49)	3	0	0.36 (0.49)	2
Iron	0	1.14 (0.46	3	0	1.01 (0.36)	4
Water pumps	1	1.03 (0.17)	2	1	1.01 (0.11)	2
Television	1	1.37 (0.68)	5	0	1.09 (0.60)	4
Mobile Phones	1	4.24 (2.20)	20	1	3.09 (1.9)	14
Washing Machine	1	1.61 (0.53)	3	0	1.16 (0.62)	4
Air Cooler	0	0.47 (065)	4	0	0.26 (0.46)	2
Cooking range	0	0.48 (059)	2	0	0.37 (0.69)	2
Fan	1	5.62 (2.20)	12	1	3.94 (1.8)	10
Water filter	0	0.13	3	0	0.02	2

		(0.40)			(0.24)	
PC/Laptop	0	1.03 (1.02)	4	0	0.47 (0.70)	3

Socio-economic Household Characteristics shown in table 4 as family size, house size, income and electricity bills with Carbon Emission in urban areas , all the respondents aligns the significant contribution to carbon emissions. The findings of this study have support from previous study, house size and energy consumption has a positive relationship due to energy-intensive appliances (Table 6) and more demand for energy in urban areas (ones, 2011). Although the link between house size and energy use is established (Wilson & Boehland, 2005; Lenzen et al., 2006), our research empirically measures this link in the peri-urban and urban Faisalabad setting using original household-level data. These results have policy implications for policymakers by determining key points of intervention to minimize household carbon footprints. Big houses and income are the major indicators of carbon emission while electricity demand for consumption plays a crucial role in urban areas (Ivanova, 2016). This is evident with findings that high demand for energy in urban areas due to more approach towards electrical appliances, the density of the population, and energy-intensive consumption (Liu X. Z., 2021). As per the finding shown in table align with a previous study, Peri-urban areas in Faisalabad city are mostly less developed, households mostly have dependence on traditional energy sources for cooking, heating, and lighting, cover long distances to find out the source of earning, energy-based home appliances and vehicles (Huang, 2022). Transport emission is a significant part of household activities as low in peri-urban areas comparatively due to fewer domestic vehicles per household, use of public transport, and limited access to leisure trips (Newman, 2019). The previous studies align with findings that higher consumption-related emission is recorded in urban areas due to the easy availability of markets and income sources although peri-urban areas have also substantial emissions from long communal routes and local domestic activities (Ivanova, 2016). Wealthy urban areas emit more carbon due to more use of energy and frequent travel mostly air travel while moderate emissions are from lower income and semi-rural life choices. At the same time, urban areas are moderate due to awareness of sustainability factors for environments and peri-urban areas emit more carbon due to the long distance from house to means of earnings. This study shows that both urban and peri-urban households participate equally but reasons for emission have been changed and recorded differently (Wiedmann, 2020).

Various noticeable socioeconomic factors influence to dominant carbon emission in the locality of urban and peri-urban areas of Faisalabad, Pakistan to deliver perceptions of sustainability. These factors consist of income level, education, age, and house size boost carbon emission at every level as well as affect the environment and global warming. The study reveals that carbon emission intensity varies between urban and peri-urban areas due to energy demand, consumption patterns, transportation modes, income level, accessibility to home appliances, and education. The urban areas households produce more carbon emissions than peri-urban areas special concerns are the housing sector and domestic use of transportation. On the other hand, households from peri-urban areas show less carbon emission due to limited access to transportation, income generation facilities, less home appliances but these are also the major contributors to carbon emission. Socioeconomic factors such as income, education level, preferences play a decisive power in the carbon emission of households. The study findings also prove with literature and theories such as EKC and sociotechnical transition that propose sustainability, economic development, and urbanization alleviate environmental depletion in the areas.

Conclusion and Recommendations

Households are the major sector with unplanned urbanization and unsuitable measures for sustainability leading to exacerbating emissions. The government's role is crucial in this matter, should design the campaigns and programs that advocate energy-efficient practices in urban and peri-urban areas. There must be the announcement of tax incentives and subsidies for houses in case they to agree the use of renewable energy sources like solar systems, insulation, and energy-efficient home appliances that can considerably cope with emissions from electricity and gas. Energy efficient and sustainable structures of buildings should float the plans to encourage emission reduction. Green urban planning concepts including solar designs, green technology, water conservation systems and energy-efficient materials should be compulsory in urban and peri-urban development areas. A massive network of Public transport should be provided in order to reduce the dependence on private vehicles. Cycling lanes, indorsing carpools, and electric public transport and private vehicle systems should be developed to reduce this sector's emission. Public attitude and changes in attitude are the major part of coping with carbon emissions at the level of the household. Advocacy campaigns should be tossed in order to educate the people about the impact of environmental depletion and their habits of consumption and energy use. This study aligns that the income level of households always plays an important role in calculating carbon emissions. To provide access to renewable energy options like energy-efficient home appliances, green technology assists emission to keep at a low level without shifting any financial burdens on households. In light of this study's findings, The researcher draws the significance of a particular conclusion that distinguishes carbon emission in urban and peri-urban areas of Faisalabad, Pakistan society from other frameworks. The custom-made strategies have been developed according to the

local circumstances and distinctive features of Faisalabad, Pakistan as Provide subsidies and tax incentives, interest-free loans, and microfinance on installing the solar system and micro gird system for peri-urban areas of Faisalabad households. Faisalabad and similar areas within Pakistan and other developing countries can convert high carbon emission society into low carbon emission through determined efforts and deployment of sustainable practices.

This research adds to the literature by giving a local custom made, experimental investigation of household carbon emissions from peri-urban and urban areas of Faisalabad, Pakistan, based on primary survey data rather than using aggregated country data. This study, unlike the current literature based on income or energy consumption, includes socioeconomic controls like household size, education level, and house size and family size, giving a complete picture of the determinants of emissions. Further, this interpret the heterogeneity of energy consumption patterns through electricity bills between peri-urban and urban households, providing useful lessons for the formulation of targeted low-carbon policies. By filling these knowledge gaps, the findings provide evidence-based policy recommendations for promoting sustainable household energy practices, making useful contributions to academic literature and practical policymaking in the area of carbon reduction strategy.

References

Ahmed, A., & Farooq, U. (2021). Comparative analysis of energy consumption in rural and peri-urban households of Pakistan. *International Journal of Energy Economics and Policy, 11(3),* 128-137

Minh, T. V. (2023). Renewable energy consumption and economic growth in Vietnam. *Energy Policy, 145*, 112345.

Chandrasekhar, D. D. (2023). how key emitters are responding to climate change, Carbon Brief explains the causes of Pakistan's deep-rooted energy crisis and how catastrophic floods fuelled its call for loss-and-damage finance at UN climate talks. *carbonbrief.org, interactive(26 May).ht*tps://www.carbonbrief.org

District, P. b. (2023). Pakistan breau of Statistics Faislabad District *https://www.pbs.gov.pk*(census-2023-district-wise/results/057).

Huang, J. R. (2022). Understanding the driving factors of household carbon emissions in China. *Energy Policy, 165*, 112927

Huiyu, J. L. (2019). Factors Controlling Urban and Rural Indirect Carbon Dioxide Emissions in Household Consumption: A Case Study in Beijing. . *Sustainability, 11(23)*(6563).

Hasan, M., & Raza, N. (2023). Income inequality and its environmental implications: A case study of Pakistan. *Journal of Environmental Economics and Policy, 6(2),* 145-162.

IPCC. (2006). Guidelines for national greenhouse gas inventories. National greenhouse gas inventories programme, Eggleston H.S., L. Buendia, K. Miwa, T. Ngara, K. Tanabe (Eds.). Institute for Global.

Ivanova, D. S.-O. (2016). Environmental impact assessment of household consumption. *Journal of Industrial Ecology,* 3(20), 526-536.

Khan, W. M. (2017). Estimation of Greenhouse Gas Emissions by Household Energy. *Pakistan Journal of Meteorology* , 14(27), 66-83.

Kothari, C. R. (2004). Research methodology: Methods and techniques. . *New Age International.*

Liu, X. Z. (2021). Carbon emissions from household energy consumption in urban and rural China: A comparison. *Energy Policy, 151*.

Lenzen, M., et al. (2006). A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India, and Japan. *Energy, 31*(2-3), 181-207.

Loru, R. (2020). Chapter three Research methodolgy 3.0. Introduction. *Researchgate.net(3).*

Miao, L. (2017). Examining the impact factors of urban residential energy consumption and CO2 emissions in China – Evidence from city-level data . *Ecological Indicators, 37*, 29-37.

Mustafa, W. (2015). Pakistan aims to cut emissions through sustainable transport. *Asia Climate Journal, 14*, 35-64.

Masood, A., Ullah, S., Ahmed, U. I., & Iqbal, M. A. (2022). Cross-country diffusion of the ISO energy management standard: How important is the neighbourhood effect? *FWU Journal of Social Sciences, 16(3)*, 21–35. https://doi.org/10.51709/19951272/Fall2022/2

Newman, P. K. (2019). The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning.". Island Press.

ones, C. M. (2011). Quantifying carbon footprint reduction opportunities for US households and communities. *Environmental Science & Technology, 45(*9), 4088–4095., 9(45), 4088-4095.

Ottelin, J. H. (2019). Household carbon footprint patterns by the degree of urbanisation in Europe. . *Environmental Research Letters, 14(11*)(114016.).

Shahbaz, M. S. (2014). Does energy intensity contribute to CO2 emissions? A trivariate analysis in selected African countries. *Ecological Indicators(50),* 215-224.

Shaikh, S. S. (2015). Pakistan crafts plan to cut carbon emissions 30 pct by 2025. reuters.com/article/climate-change-pakistan/pakistan-crafts-plan-to-cut-carbon-emissions-30-pct-by-2025.

Verma, P. K. (2021). Energy emissions, consumption and impact of urban households: A Review. *Renewable and Sustainable Energy Reviews, 147*.

Wang, S. L. (2018). Urbanization, economic growth, energy consumption, and CO2 emissions: Empirical evidence from countries with different income levels. *Renewable and Sustainable Energy Reviews, 81(2),* 44-59.

Wilson, A., & Boehland, J. (2005). Small is beautiful: U.S. house size, resource use, and the environment. *Journal of Industrial Ecology, 9(1-2),* 277-287.

Wiedenhofer, D. G.-M. (2017). Unequal household carbon footprints in China. . *Nature Climate Change, 7(1),* 75-80.

Wiedmann, T. L. (2020). Scientists' warning on affluence. *Nature Communications, 1(11).*