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RESEARCH ARTICLE

Vitality of carbon footprints of urbanites in a low-income country: Implications for low carbon society

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Abstract

Anthropogenic activities are causing climate changes and rise in average earth surface temperature as well. Developing countries are extra affected by climate changes. Pakistan is 3rd most exposed country to climate change. The carbon footprints are causing hazardous effects and pushing agencies to find ways for its reduction. This research primary objective is the estimation of the carbon footprints of households. Multistage sampling technique was used for sample selection of the 280 households of seven major roads of Faisalabad, which covered both urban and peri-urban areas. A well-structured and pre-tested questionnaire was used to accumulate the data, inserted into web's leading carbon footprint calculator for carbon footprint estimation. Urban households produce overall 3.98 tons carbon footprints per month and peri-urban produce 3.28 tons. Transportation was the major contributor towards the CO2 emissions i.e. 82% of 3.98 metric tons and 94% of 3.28 metric tons of total carbon emissions in urban and peri-urban households. There exists a positive association between CO2 emissions and family size, house size, monthly income and electricity bills of the households of urban and peri-urban areas. It is suggested that local transportation system and awareness regarding CO2 emissions and its mitigation must be improved by effective campaigns.

Keywords: Carbon footprints; Low carbon society; Households Faisalabad

Introduction

Pakistan stands 12th most exposed county to climate changes, although Pakistan's share to the global discharges of Greenhouse Gases is very less (Lenzen & Murray, 2001). Climate changes occur because of rise in sea level, average temperature and melting of glaciers. Anthropogenic activities emit greenhouse gases, mostly CO2 in the atmosphere. Major causes of GHG are forests (because of human persuaded land cover modifications causing de-forestation), power generation, transportation (produced from burning of fossil fuels), cultivation (agricultural, rice farming, livestock and burning of yield remains), manufacturing and urban activities (house, construction, transportation, waste (solid and liquefied) (Ramachandra *et al.,* 2015). Anthropological activities such as deforestation, agriculture and industrialization adds to greenhouse gases and cause climate changes (IPPC, 2007). Globally, anthropogenic activities emit approximately eight billion tons of CO2 annually (Sharaai *et al*., 2015). It's far forecasted that till the end of 21st century, in the absence of an active carbon mitigation policy, global surface temperature will rise to 2.4° to 6.4° C (IPPC, 2013). Pakistan emits 30 million metric tons of CO_2, which contributes to 0.4% of worldwide emissions, and share of carbon emission from industrialization in Pakistan is about 53% (Hanif et al. 2010; Sheikh, 2008). Industrialization, urbanization and growing vehicles are boosters of Pakistan's environmental problems (Mallick and Masood, 2011).

Rapid surge in the residents of metropolitan cities is a reason of increased energy demand which results in increased greenhouse gases (Ali and Nitivattananon, 2012). According to Environmental Protection Agency (EPA) and Japan International Corporation Agency (JICA) in Lahore, Faisalabad, Rawalpindi, Gujranwala and Islamabad acceptable particulate matter was six to seven times more than the standards of the World Health Organization (WHO) (Aziz, 2006). Carbon footprint is recently introduced phenomena, and its systems and tools are exact proven to analyze many kinds of environmental problems (Wiedmann, 2009). Carbon footprint is broadly used term for accountability and reduction of the threats of climate changes. There arises a question what correctly a carbon footprint is? Carbon footprint is many times confused with ecological footprints. Ecological footprints can be referred to a piece of productive land and sea zone that provide sustainable anthropological population (Wackernagle and Rees, 1996). On the other hand, carbon footprint states a piece of land which integrates all the CO_2 produced by humans.

Theoretically, it comprises of all the anthropogenic activities and all related sources of emission, sinks and storage of production and consumption in order to examine the effect of different conditions on climate. Carbon footprints are overall carbon emissions produced from direct and indirect sources from a product's lifecycle or emissions that are measured in units such as kilograms and tons (Sprangers, 2011). Formerly, many researchers worked on carbon footprints, but they failed to describe the relationship of carbon footprints with socio-economic features. Carbon footprints and ecological footprints provide a better scenario of demographic characteristics of households and their impact on the surroundings (York *et al*., 2003). Direct carbon footprints of households can be well-defined as the carbon emissions produced by direct use of energy such as coal, gas, oil, electricity and heating for the purpose of lighting, cooling, cooking, and transportation (Dong and Geng, 2012). While indirect carbon footprints of households is defined as carbon emissions related to the manufacturing of all other product used up by households, i.e. emissions produced from the manufacturing of furniture, food, garments and facilities (Wier *et al*., 2001).

Complete information on household characteristics such as income and consumption is needed for a proper understanding of CO_2 emissions. When income rises, emissions also go up (Baiocchi *et al*., 2010). Developed countries such as Canada, Singapore and United Kingdom are very advanced in the calculation of consumption based emissions (Barret *et al.*, 2013). The benchmarks used to compare the emissions of cities are housing facilities, transportation and lifestyle. Now, national and international agencies are very much concerned to understand the effects of GHG and CO_2 emissions to achieve sustainable development (Nakata *et al*., 2011).

Advanced and emerging countries are trying to attain such a level of sustainable development which does not depend much on carbon producing activities. This is a base for low carbon society (LCS). Abundance of families, water scarceness, destruction of land and increase in sea level stand for the causes of environmental changes in the United Kingdom. IPPC revealed courage to overcome such effects by bringing changes in prompt change and moving toward a low carbon economy (Pyrce, 2014). Low Carbon Society targets to bring down the effect of coal on the environment and achieves a sophisticated efficiency.

Income level and education quality play a prominent part in carbon dioxide emissions, when income rises the standard of living of people will go up (Mieche *et al*., 2015). Individuals would like to have their personal cars and versatility in eating habits. This study is designed to present the notion of carbon footprints of households and estimation of carbon footprints. Assessment of household's carbon footprint is freshly acknowledged, vastly advantageous since it gives standard information (Bendewald & Zhai, 2013) and shows an important role in recognizing key promoters of carbon dioxide secretions in urban zones (Gardezi et al., 2016). Diverse work have been done to examine domestic and manufacturing level carbon footprints worldwide (Shirley, Jones, & Kammen, 2012). United States Virgin Island (USVI) measured carbon footprints at domestic level, and energy was found to be the dangerous economic driver for fiscal improvement and social development. In Canada 44% of total country's greenhouse gases are produced at the domestic level (Statistics Canada, 2011). Unbelievable association exists between domestic CO2 secretions and the endowment of some practical necessities for specimen, housing and food stuff (Druckman & Jackson, 2008)(see Table 1).

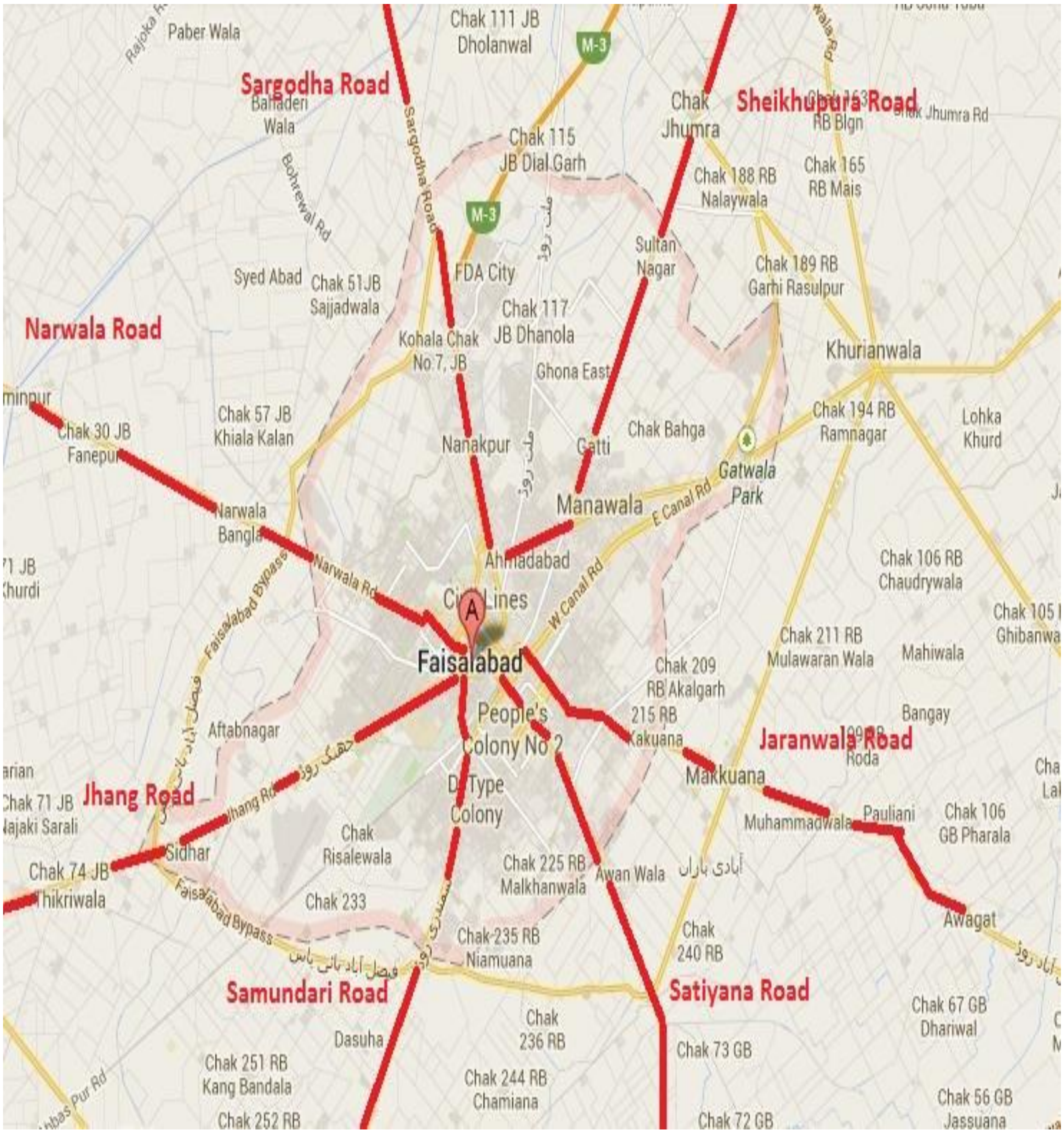

Figure 1. Map of Faisalabad displaying research area

Unfortunately constrained information about carbon footprints in Pakistan has headed to various reservations to pass on employable atmosphere rectification strategies. Faisalabad is the third biggest city of Pakistan, after Karachi and Lahore, so it is assigned as the circumstantial analysis region Figure 1. Household carbon footprints were assessed by case study technique. We intended to make a comparison of carbon emissions of urban as well as peri-urban zones of Faisalabad city and to detect factor(s) that augment carbon footprints.

Theoretical background

Origin of Carbon Footprint

“The origin of carbon footprint can be well-defined as a subgroup of "ecological footprints" (Wackernagel and Rees, 1996). “Ecological footprint denotes to biologically useful prerequisites for land and oceanic zone to support many residents as worldwide housing.” Conferring to this concept, carbon footprint refers to the basic surface of human CO2 emissions period” (Pandey et al., 2011). "The carbon footprint is a quantity of the high-class total amount of CO2 emissions that is directly and indirectly originated by an action or is gathered from the life phases of a product." (Wiedmann and Minx, 2008).

Figure 2. Factors responsible for carbon footprints

Classification of Carbon footprints

Direct carbon footprints

Direct carbon footprints of households can be well-defined as the carbon secretions produced by direct use of energy such as firewood, gas, oil, electricity and heating for the purpose of illumination, cooking, refrigerating and transportation (Dong and Geng, 2012).

Indirect carbon footprints

While indirect carbon footprint of households can be well-defined as carbon secretions created from manufacturing of furniture, garments food and services (Wier *et al.,* 2001).

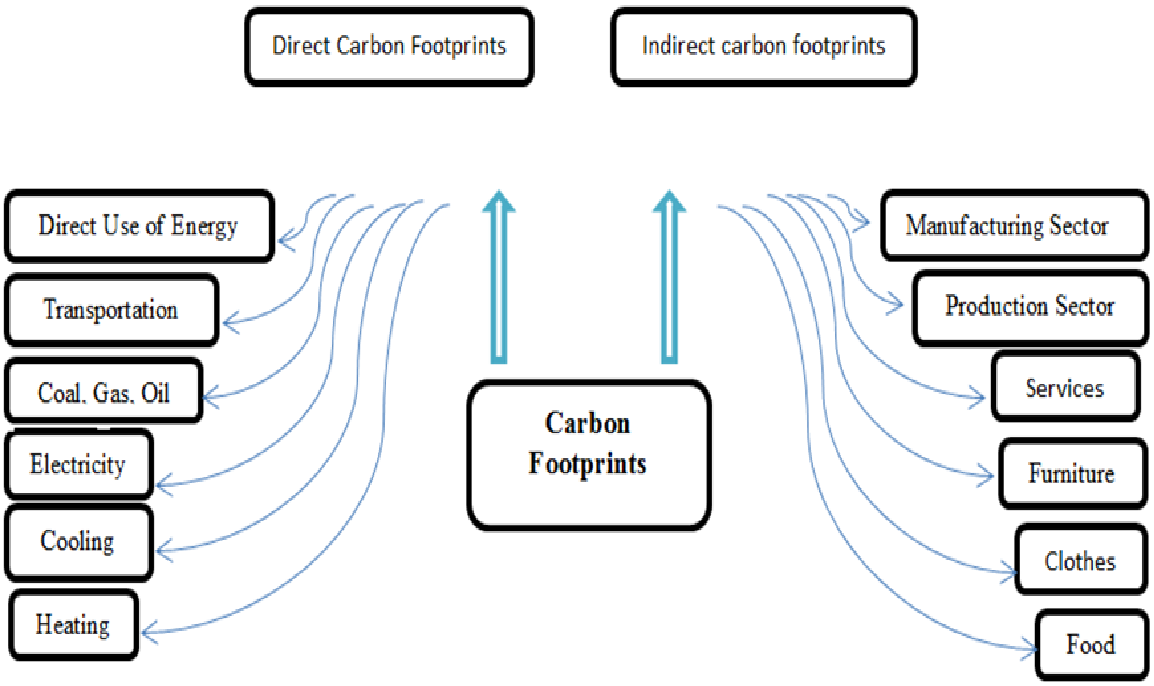

Figure 3. Classification of factors of direct and indirect carbon footprints

Measurement of Direct and Indirect Carbon footprint

Direct carbon footprint of households

The equation given below can be used to calculate direct household carbon footprints (Change, 2006).

$$\text{CFd} \sum_{i=0}^{n} Mi \times \text{EFi}$$

CFd denotes direct household carbon footprint,
i denotes the kind of energy used, like coal, liquid petroleum gas (LPG), heat and current,
Mi denotes the quantity of usageof energy type I,
EFi states carbon secretion element of energy used for energy type i.

Indirect household carbon footprint

There are two leading approaches for computing indirect carbon footprints of households.

1- Input output analysis (Cohen et al., 2005)
2- Questionnaire analysis (Pachauri, 2004)

The equation below shows how to compute indirect domestic carbon footprints.

$CF^e = F \times E = F \times D\ (I - A)\ -1$

Where CFe denotes the total secondary household carbon footprint,

E is trajectories of indirect discharges strength and D symbolize the direct emission strength of manufacturing sectors,

F represents the matrix of domestic final consumption,

I denote a characteristic matrix, A represents direct intermediary input quantity matrix.

The calculators of carbon footprint accessible available have presented promising calculations worldwide. Numerous studies have repetitively proven that input statistics either in apparent to in depth form can be examined by means of online calculators to represent anthropological influence on the environment (Pandey, Agrawal, & Pandey, 2011).

Statistical Analysis

Information was analyzed for mean, frequencies, standard deviation, and correlation to find the relationship between household factors and carbon secretions.

Materials and Methods

Data

This case study was conducted in urban and peri-urban zones of Faisalabad City. These localities were selected from seven major roads of Faisalabad city. These roads include Jhang road, Jaranwala road, Sheikhupura road, Satyana road, Sargodah road, Samundri road and Narwala road. From each road four areas were selected using multistage sampling technique. Multistage sampling is extended form of cluster sampling, which is demonstrated as If the whole area of concern occurs to be a big one an appropriate manner in which a sample can be studied is to split the area into a numeral of smaller non overlying areas, and then to randomly choose a numeral of these smaller areas generally called clusters **(**Kothari, C. R. 2004**).** Multistage sampling is an additional expansion of the standard of cluster sampling. (1) It can be easily administered than many single stage designs (2) An enormous number of components can be sampled for a given cost under multistage sampling because of chronological clustering where this is not conceivable in most of the simple designs. (Kothari, C. R. 2004). These four areas from each road were further equally divided into two urban and two peri-urban areas. A basic criterion for the selection of urban and peri-urban areas was to make an interesting comparison of these areas to access their carbon footprints.

A self-designed questionnaire was used to collect primary data concerning socio-economic variables from each zone randomly. Sample of 280 households were filled by the households of selected areas. Those 280 questionnaires were filled on the basis of home consumption of electricity, gas and petrol/CNG. Data of electricity (kWh) and gas (hm3) were collected by observing household monthly bills. The data on transportation, distance journeyed in (Km) of all household members from their home to places of work and burning of petrol (L) and CNG (Kg) were also inquired in the questionnaire. While the expenditure on food, clothing, education, and some other subordinate factors were also collected according to the necessity of study. Data were gathered from urban and peri-urban households situated in different areas of Faisalabad city and the questionnaire consist of parameters given in Table 2.

The sample is considered representative of the broader Faisalabad region due to the inclusion of seven major roads covering diverse geographic and socioeconomic areas of the city. By applying a multistage sampling technique and randomly selecting households within both urban and peri-urban settings, the study captured a wide range of income groups, household sizes, education levels, and lifestyle practices. This comprehensive coverage enhances the generalizability of the findings to the broader population of Faisalabad.

Carbon footprint calculations

The collected information was putted into the online calculator to calculate the carbon footprints available at (http://www.carbonfootprint.com/calculator.aspx). The total amount of household carbon footprints can be measured as the product of domestic consumption. The household carbon footprints (HCF) are usually measured by employing the equation given (Shirley et al., 2012).

HCF (tCO_2e) = Average Annual Expenses × Emissions Factor

An emission factor can be defined as an expected value of every factor. An emission element of carbon footprints is the average quantity of carbon dioxide produced for each unit of consumption.

Table 1: Variables used in Study

Household energy usage	Socio-economic variables	Tributary factors
Electrical energy (kWh per month)	House Size (Marlas)	Fashion consciousness
Natural gas (HM3 per month)	Total family Members	Recycling
Transportation (km per month)	Income (in Rs.) per month	Furniture and electrical equipment
Food (liking type of food)	Number of earners	Recreation routine
Fuel (For home heating)	House location	Finance

Household variables used in survey for data gathering

Results and discussion

Faisalabad stands amongst the most residential urban groups of Pakistan, with a population of 2,506,595. Domestic features considered in the study of household secretions and information collected from carefully chosen residents are offered in Table 3 and 4. Figures about house size, family size, monthly domestic income, number of automobiles retained and other variables, containing food, petrol, transportation, are offered here. Emission source wise distribution of carbon footprints clearly shows that urban households are having higher carbon footprints than that of peri-urban households and urban households produce 3.98 tons carbon footprints per month and peri-urban produce 3.8 tons which considerably less Table 5. Four classifications of monthly metric ton carbon footprints of urban and peri-urban areas are presented in Figure 3 which demonstrate that 20 out of 140 urban households are producing up to 4 metric ton of monthly carbon footprints and in peri-urban areas only 3 out of 140 households are held in this ratio. The leading reason for higher carbon footprints in urban areas is their luxurious standard of living and high usage of energy. As income rises, household's members lean towards achieving higher carbon sets, which they consider costly formerly (Weber & Matthews, 2008). Higher transportation and electricity increase carbon emissions directly, and other elements like, reutilizing, refreshment, food, mode lifestyle and clothing increase indirectly (Tukker & Jansen, 2006). These results can be related with the work of Druckman and Jackson (2008), showing that in United Kingdom high quantity of household CO2 secretions is because of nonstop energy consumption.

Table 2: Statistical description of urban and peri-urban areas of Faisalabad city

Variables	Urban (n=140)	Peri-urban (n=140)
Income of households		
Up to 50000	68	111
Up to 100000	50	27
Up to 150000	8	2
Up to 200000	14	0
House Status		
Own	119	127
Rented	21	13
House Size (Marla's)		
Up to 3	59	104
Up to 6	70	35
Up to 10	11	1
Transport mostly used to go out		
Walk	23	71
Bike	95	51
Car	12	9
Bus	10	9
Flying routine		
Monthly	5	0
Biannually	4	2
Annually	33	15
Rarely	98	123
Newspaper purchasing behavior		
Daily	18	4
Weekly	19	8
Monthly	15	6
Never	88	122
Laundry routine		
Weekly	70	80
Twice in a week	9	3
Monthly	45	45
Twice in a month	16	12
Fuel used for cooking		

Natural Gas	139	103
Wood	1	10
Oil	0	21
Bio Gas	0	32
Dunk Cake	0	20
Coal	0	21
Fuel used for home heating		
Natural Gas	128	1
Wood	2	6
Paraffin Oil	6	1
Dunk Cake	1	24
Coal	3	9
Shopping routine		
Weekly	19	2
Twice in a week	5	2
Monthly	54	25
Not specific	62	111
Recreation routine		
Weekly	15	1
Twice in a week	7	0
Monthly	32	5
Annually	22	27
Not specific	64	107
Do the family is brand/fashion conscious?		
Yes	101	38
No	27	69
Sometimes	22	33
Do you turn off lights when you leave room?		
Yes	116	115
No	6	12
Sometimes	18	13
Do you close windows when heater/AC is on?		
Yes	119	118
No	11	9
Sometimes	10	13
Do you cover cooker/Pan while cooking food?		
Yes	94	120
No	15	9
Sometimes	31	11
Do you unplug appliances/chargers when not in use?		
Yes	84	93
No	22	21

Sometimes	34	26
Do you turn off the water while brushing your teeth?		
Yes	79	88
No	35	32
Sometimes	26	20
Does your family recycle products e.g. plastic, aluminum?		
Yes		
No	35	53
Sometimes	92	72
	13	15
Do you leave your PC or TV on standby for long time?		
Yes		
No	53	63
Sometimes	72	66
	15	11
Do you turn off your computer/electronics when not using?		
Yes		
No	101	114
Sometimes	19	21
	20	5
Do you leave mobile charger on in the plug when not using?		
Yes		
No	41	42
Sometimes	76	70
	23	28

Statistical description of urban and peri-urban areas of Faisalabad city w.r.t. frequency

Table 3: Statistical description of urban and peri-urban areas of Faisalabad city

Variables	Urban			Peri-urban		
	Min	Mean (SD)	Max	Min	Mean (SD)	Max
Respondent Age (Years)	16	34.6 (12.5)	72	15	39.2 (14.2)	76
Responsive Education (Years)	0	10.59 (5.8)	21	0	7.30 (5.3)	18
Total Family Members	2	6.7 (2.81)	21	2	7 (3.5)	24
Electricity bill (Summer)	900	11029.47 (10928.52)	50000	448	3686.25 (2716.54)	14414
Electricity bill (Winter)	132	3939. 45 (4021.62)	20000	123	1349.75 (914.71)	4500

Gas bill (Summer)	170	546.54 (719.04)	5000	0	1235.16 (1196.24)	2200
Gas bill (Winter)	180	270.38 (336.51)	7000	0	503.74 (527.67)	4070
Cooking Oil (Liters)	4	5.91 (1.90)	15	5	6.87 (2.03)	15
Dressing (Rupees per month)	1000	8023 (6800)	40000	500	4300 (3691)	25000
Food (Rupees per month)	1500	1941 (1275)	51000	1000	1356 (7274)	40000
Grooming, Medicine (Rupees per month)	500	3561 (2475)	10000	500	2589 (2947)	20000
Education (Rupees per month)	0	6934 (6484)	25000	0	5087 (6327)	30000
Phone, Internet (Rupees per month)	100	1999 (1405)	8000	200	1367 (1173)	500
No. of Smokers (per family)	0	0.54 (0.86)	6	0	0.55 (0.70)	4
Cigarettes burned (per day)	0	2.7 (4.7)	16	0	5.2 (7.7)	33

Statistical description of urban and peri-urban areas of Faisalabad city w.r.t. minimum and maximum

Table 4: Distribution of carbon footprints in urban and peri-urban areas

	Urban			Peri-Urban		
	Emissions in metric ton (Per Month)					
Source	Min	Mean (SD)	Max	Min	Mean (SD)	Max
From House (Electricity, Gas, Cooking oil)	0.03	0.1296 (0.17)	0.99	0.02	0.0782 (0.06)	0.23
From Transport (Plane, bike, Car, Bus)	0.02	0.8354 (1.1)	3.29	0.02	0.3769 (0.58)	3.10

From Secondary Sources	0.016	0.8251 (0.83)	2.520	0.09	0.9805 (0.57)	2.02
Total	0.26	1.7864 (1.1)	3.98	0.17	1.4232 (0.74)	3.28

Emission source wise distribution of carbon footprints in urban and peri-urban areas

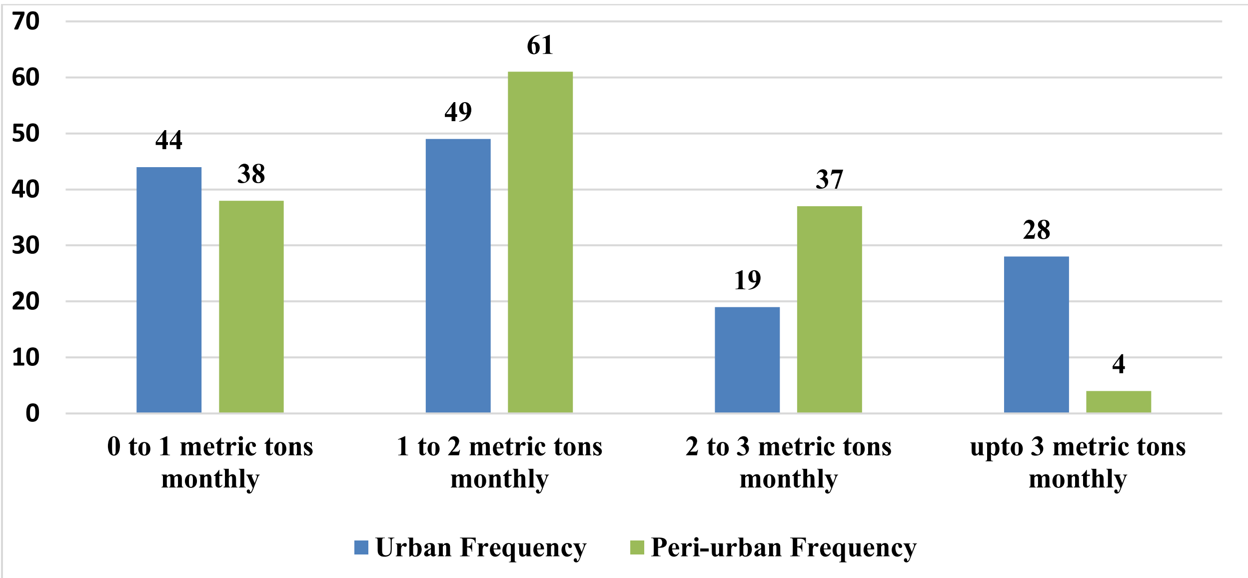

Figure 4. Categorical distribution of carbon footprints in selected areas

Table 5: Correlation matrix and results

	1 Carbon footprints	2 Family Size	3 House Size	4 Income	5 Electricity bill
	URBAN CORRELATION				
Carbon footprints	1				
Family size	7.62 (r=0.1299) (p=.1261)	1			
House size	5.69 (r=0.2898) (p=.005)	(r=0.059) (p=.486)	1		
Income	83264.29 (r= 0.318) (p=.001)	(r=0.335) (p=.695)	(r=0.365) (p=0.00)	1	
Electricity bill	3686.5 (r=0.380) (p=.000)	(r=0.335) (p=.019)	(r=0.443) (p=.000)	(r=0.362) (p=.000)	1

	PERI_URBAN CORRELATION			
Carbon footprints	1			
Family size	7.89 (r=0.335) (p=0.000)	1		
House size	4.96 (r=0.378) (p=.000)	(r=0.354) (p=.000)	1	
Income	41864.89 (r=0.346) (p=.000)	(r=0.389) (p=.000)	(r=0.303) (p=.003)	1

Electricity bill	3686.5 (r=0.112) (p=.187)	(r=0.206) (p=.014)	(r=0.049) (p=.557)	(r=0.257) (p=.021)	1

Correlation matrix of home size, family size, monthly earnings, electricity bill of summer and carbon footprint per household of urban and peri-urban areas of Faisalabad are denoted via their mean value and correlation values, and their level of significance as well Table 5. Urban areas and peri-urban displays highly noteworthy addition in per family carbon footprint when their family size increases (r=0.1299 p=.1261) and (r=0.335 p=.000) respectively. When family size increases, the consumption also increases, which results in higher carbon footprints. Family sizes in urban areas are smaller than that of peri-urban because they are educated and well aware of the benefits of smaller families. The correlation between house size (Marla's) and carbon footprints is also greatly significant, mutually in urban and peri-urban areas. Urban areas show extremely significant rise for each family's carbon footprint when their monthly income increase (r=0.318 p=.001). Even though in urban areas the members of the family are more limited than peri-urban areas, however, they all have higher contribution in income which fallouts in greater carbon footprint.

Conclusions

This century is an age of up-to-date technology, and, people are using these technologies for their comfortable and making their lives better. The carbon emissions produced from anthropogenic activities and changing climate are placing an abundant stress on the operative use of such tools and the encroachment of defensible development. This issue gives rise to the notion of the Low carbon Society to attain sustainable development. There is a serious need of attention in Pakistan to convert speedily mounting urbanized areas into a lesser carbon society. At this time, more than 30 metric tons of yearly carbon emission is documented, which in universal emission interpretations only 0.4%. Although that one share is small globally, the nationwide values settled nearly four times from the time 1980,when it was merely 9 million metric tons. This study clearly indicates that housing and way of life in urban areas are extravagant with higher carbon footprints. It is suggested that improvement of green transport, less fuel usage, building engineering and urban scheme will ultimately develop effectiveness in an energy presentation that would lead to build low carbon urbanized areas. Some proposed suggestions which were given by respondents are presented in Figure 4, which can be followed by household to achieve a low carbon society. While the findings suggest actionable strategies for reducing household carbon footprints such as promoting green transport, efficient energy use, and awareness campaigns several challenges could hinder implementation. Economic constraints in peri-urban households limit access to sustainable technologies. Infrastructure deficiencies, including unreliable or absent public transportation, further restrict options. Moreover, public understanding of carbon emissions and their consequences is generally low, and cultural preferences often favor conventional practices over sustainable alternatives. Finally, policy limitations, such as inadequate regulatory enforcement and lack of targeted incentives, may delay the transition to low-carbon behaviors. A multi-pronged strategy involving government support, local planning, and community-based education is essential to overcome these barriers.

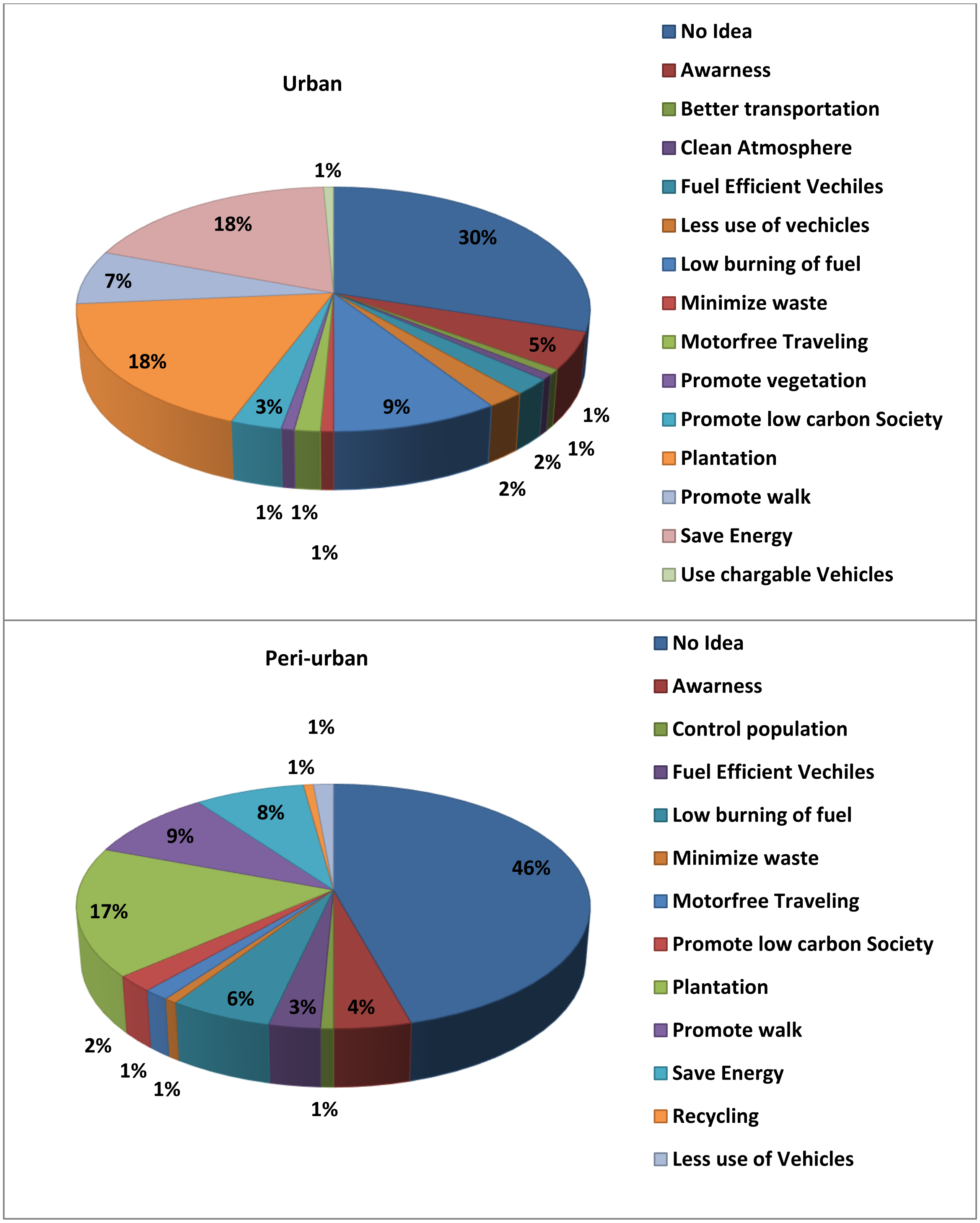

Figure 5. Suggestion given by respondents to reduce carbon emissions

Table 5: CO_2 emission estimates using several household factors

Country (Year)	Reference	Carbon Tracking Method	Parameters (Estimates)
China 2017	Yang & Liu 2017	Based on IPCC CO_2 Emissions (fuel usage × [fuel carbon content * fuel calorific value * fuel oxidation rate] × emission factor	Cooking & Heating (43%) Transportation (30%) Space Heating (27%)
UK 2016	Allinson et al., 2016	CO_2 Emission = Consumption × Emission Factor	Gas (46%) Electricity (32%) Personal Transport (22%)
USA 2008	Weber & Matthews, 2008	CO_2 Emission = Consumption × Emission Factor	Education (2.5%) Health (7.5%) Dressing (3.3%) Others (10%) Utilities (25.8%) Furnishing (3.3%) Communication (1.6%) Housing (4.1 %) Tobacco (1.6%) Hotels & restaurants (4.1%) Food & Drinks at Home(6.6%) Personal Transportation (26.6%) Refreshment / Culture (2.5%)
US 2012	Shirley et al, 2012	Cool Climate Network (Online Carbon Calculator) CO_2 Emission = Consumption × Emission Factor	Transportation (24%) Home-based Energy (31%) Services (8%) Food (18%) Waste & Water (9%)
US 2008	Padgett et al., 2008	Online carbon Calculator	Electricity (26%) Gas (17.3%) Fuel Oil (22.5%) Air Travel (0.8%) Propane (16.6%) Personal Vehicle usage (16.5%)
US 2009	Kim & Neff, 2009	Online Carbon Calculator	Transport (94%) Energy Usage (84%) Recycling (35%) Food (25%) Water (18%)

			Others Purchasing (14%)
China 2007	Tian Geng, Dong et al., 2016; Tian, Geng Dai et al., 2016	CF= ΣM × EF	Raw Coal Burning (4.61%) Other Washed Coal (1.2%) Gas (1.09%) LPG (0.09%) Heating (15.6%) Electricity (10.5%) Food (17.1%) Clothing (9.9%) Facilities (4.4%) Health (7.7%) Transport (1.3%) Education (16.4%) Housing (4.4%) Others (7.4%)
Estonia 2011	Brizga, Feng, & Hubacek, 2017	Input Output Model	Food & Drinks (17.1%) Clothing & Footwear (1.81%) Housing, Electricity, Gas, fuel, water (41.8%) Furnishing, maintenance of house (7.2%) Health (1.81%) Transport (18.1%) Communication (0.9%) Hotel & Restaurants (3.6%) Other goods & Services (1.8%)
Latavia 2011	Brigza et al., 2017	Input Output Model	Food & Drinks (29.8%) Clothing & Footwear (1.49%) Gas, fuel, water & Electricty (26.8%) Furnishing, maintenance of house (7.4%) Health (7.4%) Transportation (20.8%) Communication (0%) Refreshment & Culture (5.97%) Education (0%) Hotels & Restaurants (2.9%) Others (2.9%)
Lithuania 2017	Brizga et al., 2017		Food & Drinks (30.8%) Clothing & Footwear (2.46%) Housing, Gas, fuel, water & Electricty (16%) Furnishing, maintenance of house

			(13.5%) Health (1.2%) Transportation (30.8%) Communication (0%) Refreshment & Culture (2.46%) Education (0%) Hotels & Restaurants (1.23%) Others (1.23%)
Korea 2013	Kim & Kim, 2013	Carbon Intensities (tCO_2) = Consumption × Emission Factor	Electricity Summer (79%) Electricity Winter (59%) LPG Summer (34%) LPG Winter (15%)

Literature review relating to CO_2 emission estimates using several household factors

Declaration
we, hereby declare that this research is the result of our independent work, and all sources used have been appropriately cited and take full responsibility for the integrity and originality of the contents presented herein.

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Conflict of interest: This study was conducted with a commitment to upholding the highest ethical standards throughout all stages of research design, data collection, analysis, and reporting.

Ethics approval/declaration: This study will comply with all ethical standards for research involving human participants. Participants will be informed about the purpose, procedures, and voluntary nature of the research, and all information will be handled with strict confidentiality.

Consent to participate: Informed consent will be obtained from all participants prior to their involvement in the study. Participants will be assured of their right to withdraw at any point without any consequences, and their data will only be used for academic purposes as outlined in the consent form.

Consent for publication: Consent for publication will be obtained from participants where applicable, especially if any identifiable information, quotes, or case details are used. All data will be anonymized to ensure participants' privacy and rights.

Data availability: The datasets generated or analyzed during the current study will be available from the corresponding author upon reasonable request. In compliance with data protection regulations, personal and sensitive data will be stored securely and will not be shared publicly.

Authors contribution: Muhammad Usman Nawaz: Conceptualization, literature review, methodology design, data collection, statistical analysis, and writing original draft. Hongguang Ma: Supervision, guidance on research design, validation of results, and critical revision of the manuscript. Kousar Noreen: Support with data interpretation, visualization, and writing review and editing. Sadaf Nazeer:

Drafting orgional writing and Assistance with referencing, proofreading, and formatting according to journal standards.

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