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Understanding the impact of lifestyle on individual carbon-footprint

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Abstract

According to the International Energy Agency, India is the fourth largest emitter of global greenhouse gas (GHG) emissions contributing about 5% of total emissions [1]. But it is also the home to a third of the world's poor. There also exists a large disparity in the living conditions and lifestyles of people living in the rural and urban India. Based on geographical location and lifestyle, an individual's contribution to the global carbon footprint has been estimated in this study. Data on consumption of goods and services resulting in GHG emissions was gathered at the household level through a door to door survey from few localities in Mumbai and rural areas within 100km of boundary. Equivalent carbon emission factors were used to estimate the carbon footprint from major sources like electricity, transport, cooking fuel and food for these areas. The average annual per capita carbon footprint was estimated to be 2.5 tons CO_2e in the urban area and 0.85 tons CO_2e in the rural area. For each of the areas (rural and urban), substantial variation in carbon footprint has also been observed across different socio-economic classes. Limitations: Indirect emissions, emissions related to work and public place were excluded. This study looked at the sectoral contribution (activity-wise, e.g. cooking, transportation etc.) as well as the rural-urban disparity in the individual carbon footprint; which was done for the first time in India.

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1. Introduction

Rising population and concentration of industrial activities in mega-cities are transforming them into source centres of air pollution. Urbanization and energy-intensive economic development are determining factors for emissions of GHGs. Activities such as urban transport, solid waste disposal, domestic fuel use, industrial activities and power generation for meeting the energy demand of the cities generate a considerable amount of GHGs along with other air pollutants. Even in the rural areas of the developing nations the use of traditional fuels, like wood, animal waste and crop residues, has local environmental impacts due to significant emissions of pollutants such as SO_2, NO_x, etc. along with emissions of GHGs like CO_2, CH_4 and N_2O. Carbon footprint is used as an indicator to measure and compare the impact due to such activities across geographies. Carbon footprint is the overall amount of CO_2 and other GHG emissions expressed as CO_2 equivalent associated with a product, along its supply-chain and sometimes including emissions from use and end-of-life recovery and disposal.

India has traditionally been an agricultural country with majority of its population residing in the villages. Even though India's per capita GHG emissions of 1.3 tonnes are well below the world average of 4.4 tonnes (Prayas, Energy Group, 2009), it is the 4th largest global GHG emitter due to its large population. Hence, India's development pathway and corresponding GHG trajectory would have significant implications for the climate change problem. Some developed countries claim that city dwellers have smaller carbon footprint than their rural counterparts. For example, a New Yorkers annual carbon footprint is 7.1 tonnes of CO_2 per capita whereas for US the average annual per capita carbon footprint is approximately 20. Similarly, a Londoners annual carbon footprint is 6.2 tonnes of CO_2 per capita and the average number for UK is approximately 11 [2]. Could this be true for India as well? The present study is motivated by these factors and the following objectives are attempted:

1. To identify the major factors contributing to the individual carbon footprint
2. To understand the relative contribution of various factors to the carbon footprint
3. To study effect of one's geographical location and socio economic status on carbon footprint

There are few studies reported on the urban and rural CO_2 emissions. (GreenPeace India Society, 2007) deals with the comparison of urban and rural household emissions and emissions' distribution among different income classes of India. This study used the bottom up approach for data collection by conducting direct interviews with people who spent a maximum amount of their time at home so as to obtain accurate assessment of energy consumption in the house. A similar comparative study has been done for the households in the UK with a different approach (Druckman and Jackson, 2009). It presents socio-economically disaggregated framework for attributing CO_2 emissions to people's high level functional needs. Based around a quasi-multi-regional input–output (QMRIO) model, the study, in theory, takes into account all CO_2 emissions that arise from energy used in production of goods and services to satisfy the UK household demand, whether the emissions occur in the UK or abroad. Studies in (Garg et al., 2001) provide the inventory of GHG (CO_2, CH_4, and N_2O) emissions for whole India at a national and sub-regional district level. (Kadian et al., 2007) provide the inventory of energy related GHG emission from the household sector in Delhi. (Chakravarty et al., 2009) presents an overview of trends in energy and carbon intensity in the Indian economy, with some insights into their drivers and ongoing policy initiatives in the energy sector that will benefit low carbon growth. (Prayas, Energy Group, 2009) presents a framework for allocating a global carbon reduction target among nations, in which the concept of ''common but differentiated responsibilities'' refers to the emissions of individuals instead of nations. The income distribution of a country is used to estimate how its fossil fuel CO_2 emissions are distributed among its citizens, ultimately leading to global CO_2 distribution.

The present study is focused on the estimation of the household carbon footprint for a variety of people living in and around Mumbai (Bombay). Mumbai is located on the western coast of India and is the fourth most populous city in the world. The population of the total metropolitan area of Mumbai is close to 20.5 million. It is the wealthiest city in India and consists of 7 islands. The city is surrounded by suburban and rural areas and a major part of the population residing in these areas commute to Mumbai for their occupation mostly using public transportation i.e. local trains and buses.

2. Methodology

2.1 Data collection:

In the present study, household level data on consumption of goods and services resulting in GHG emissions was gathered through door to door interviews. A questionnaire including the personal details of the members of every household was prepared to estimate the GHG emissions due to electricity, food consumption, cellphone usage, waste generation and transportation.

In order to cover the diversity in living habitats, two types of location were chosen: rural (villages about 100 km from Mumbai) and urban (parts of Mumbai city). A total of 97 households were surveyed.

2.2 CO_2 equivalent emission factors:

In order to estimate the combined impact of emissions of all of the different greenhouse gases, mass emissions of the non-CO_2 greenhouse gases are converted into the CO_2 equivalent emissions using their Global Warming Potential GWP. The CO_2 equivalent emission factors for the various sources are given in Table 1.

Table 1: The CO_2 equivalent emission factors (CO_{2e} factor)

		Liquid Fuels	
Sr. No.	**Sources**	**g of CO_{2e} per L of fuel**	**Reference**
1	Petrol	2207	[3]
2	Diesel	2650	[3]
4	Kerosene	2519	[3]
		Other Fuels	
Sr.No.	**Sources**	**g of CO_{2e} per kg of fuel**	**Reference**
1	CNG	2692	[3]
2	LPG	2985	[3]
3	Wood	1597	Bhattacharya et al., 2002
		Travel	
Sr. No.	**Sources**	**g of CO_{2e} per km of distance travelled**	**Reference**
1	Air travel (domestic)	195.18	[4]
2	Air travel(international)	96.35	[4]
3	Travel by Train(long distance)	41.5	[5]

4	Travel by local train	31.7	[5]
5	Rural Auto (Petrol)	30	[3]
		Food	
Sr. No.	**Sources**	**g of CO_{2e} per kg of food item**	**Reference**
1	Rice	1220	Pathak et al., 2010
2	Wheat	120	Pathak et al., 2010
3	Milk	729	Pathak et al., 2010
4	Poultry meat	846	Pathak et al., 2010
5	Eggs	588	Pathak et al., 2010
6	Fish	718.3	Pathak et al., 2010
7	Potato	24.9	Pathak et al., 2010
8	Cauliflower	28.2	Pathak et al., 2010
9	Brinjal	31.1	Pathak et al., 2010
10	Banana	71.6	Pathak et al., 2010
11	Apple	331.4	Pathak et al., 2010
		Miscellaneous	
1	Electricity	820[a]	Central Electricity Authority, 2011
2	Cellphone	57[b]	Berner M., 2010
3	Municipal Solid Waste	1490[c]	[6]

2.3 Carbon footprint calculation:

The carbon equivalent emission-factor was used to find the carbon footprint contribution from each source. The data collected from the survey was first converted into appropriate units. The per capita carbon footprint due to each source was calculated using the corresponding factors from Table 1. The carbon footprint calculation methodology along with the assumptions for each source is explained below:

[a] Emission factor in g of CO_{2e} per kWh
[b] Emission factor in g of CO_{2e} per min of talk-time
[c] Emission factor in g of CO_{2e} per kg of waste

1. Electricity: In the survey each family was asked about their average monthly bills and the unit rate for electricity in their area. Then the annual electricity consumption was calculated and was multiplied with the CO_{2e} factor for electricity to get the carbon footprint (kg CO_{2e} per year) for each household. The CO_{2e}

factor due to electricity for Northern Eastern Western and North-Eastern (NEWNE) grid is 0.82 kg of CO_{2e} per kWh of electricity (Central Electricity Authority, 2011).

2. Travel: In the survey each family was asked about the average distance travelled by them for different purposes i.e. occupational, educational, leisure/weekend trips and trips to relatives along with the mode(s) of transport used for each travel purpose and the mileage for the personal vehicles used. The CO_{2e} emission factor for each mode of public transport has been considered separately. The direct factors were available only for the major public transport modes [4, 5] and the fuels used for the vehicles [3]. For the vehicles such as bus, auto etc whose factor is not directly available, the emission factor was estimated based on the mileage and the typical occupancy of these vehicles in the area. Typically the buses and auto rickshaws in urban areas use CNG, while those in rural areas use diesel and petrol, respectively.

Thus the annual carbon footprint due to usage of each mode of transport was calculated for each household by using the corresponding emission factors and multiplying them by the distance travelled by that mode of transport in that year.

3. Waste: Every household was inquired about the average quantity of waste generated every day and thus annual waste disposed by each household was calculated. In this study, the composition of Municipal Solid Waste (MSW) [7] has been considered as:

Food waste - 33.9%, Paper/cardboard - 23.2%, Wood - 6.2%, Textiles - 3.9%, Rubber/leather - 1.4%, Plastic - 8.5%, Metal - 4.6%, Glass - 6.5%, Others-9.8%

Based on this composition the CO_{2e} factor has been taken as 1.49 kg of CO_{2e} per kg of waste [6]. The annual waste generated was multiplied by this factor to get the carbon footprint due to waste.

4. Food: Every household was asked about the amount of various food items for example food grains, vegetables, fruits, milk, eggs and non-vegetarian food they consume.

The emission factors for different type of food items are listed in Table 1. In the absence of the exact data on consumption of individual fruits and vegetables, an average emission factor for food category “fruits and vegetables” was used. Similar approach was used for the non-vegetarian food items as well. CO_{2e} factor for fruits and vegetables was calculated to be 0.097 kg of CO_{2e} per kg of fruits and vegetables and for non-vegetarian food items it was calculated to be 0.78 kg of CO_2 per kg of non-vegetarian food. These average emission factors were used to estimate the contribution of various food items in the overall for each household.

5. Other fuels*:* In the survey people were asked about the types and amount of fuel used (wood, kerosene, coal, LPG) for different purpose like cooking, water heating etc. every month. Typically, domestic LPG cylinder contains 14.2 kg of LPG. The emission factors in Table 1 were used to estimate the carbon footprint of fuel usage.

2.4 Limitations

The present study depends on the primary data collection through household interviews. This has resulted in various limitations due to lack of complete details from the households.

- The emissions at work place or due to any other occupational purpose were excluded in this project mainly due to the high level of complexity involved with variations in the workplace environment and profiles
- Lifecycle emissions assessment from the housing and appliances were not included
- It is difficult to obtain the exact composition and details about the food consumption of people.

- The limitations faced in the present study are also derived from the lack of availability of direct measurements for certain CO_2 emission sources. In such cases, indirect measurements or other related data were used.
- All the numbers related to energy consumption are "reported" by people and not "measured". This may lead to some personal errors in the estimation.

3. Results

Based on the method explained in the previous section, carbon footprint was calculated for every household surveyed and the data was then analyzed.

3.1 Rural Carbon Footprints

In all 51 households from 6 villages (Khadki, Maldiv, Kapshi, Vihigaon, Tamnath and Shirshe) - about 100 kms from Mumbai, were surveyed as part of this study. The average number of members in these households was 5 ranging from 2 to 13. From the survey, it was observed that the electricity consumption (per month) for rural areas ranges from 6 kWh to 48 kWh per capita depending on the household income. Very few people in villages use motorized vehicles, some of them are farmers who own land in the same village and some commute to nearby towns and cities daily for work purpose. Thus the range of distance travelled (per year) is vast, from 430 km to 13,450 km per capita. The diet of rural people mainly consists of rice; fruits and vegetables are only consumed in rich families in villages. Wood and kerosene are mostly used for cooking; LPG is used only by few families due to high cost and low availability.

This section compiles all the results obtained from rural area across the various income groups. Based on the annual income of each household they were divided in 3 groups:

1. < INR 30,000
2. INR 30,000 to INR 100,000
3. > INR 100,000

Figure 1 gives the relative contribution of the various sources to the total carbon footprint across the 3 income groups.

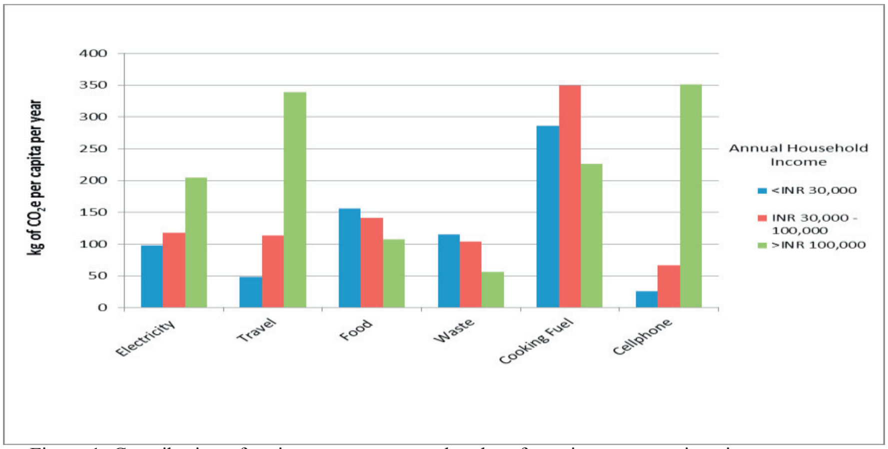

Figure 1: Contribution of various sources to rural carbon footprint across various income groups

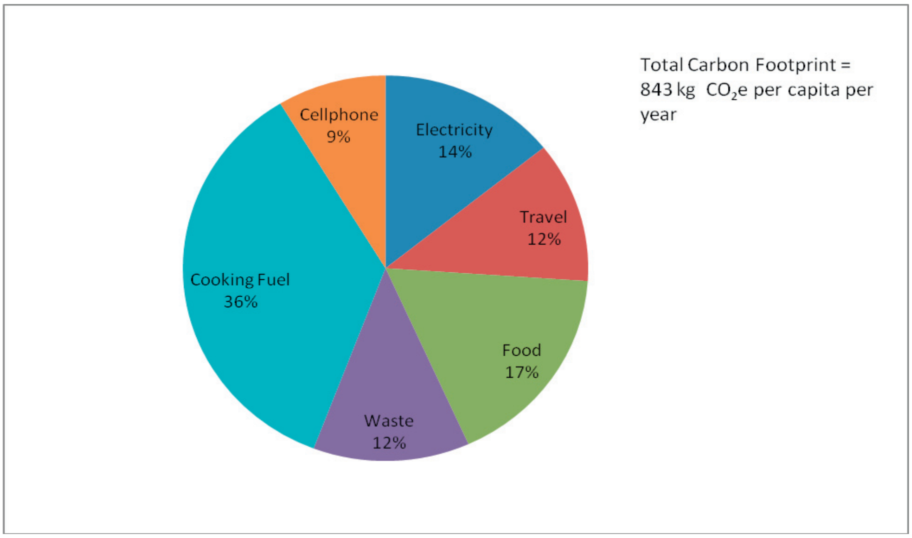

Figure 2: Break up of average carbon footprint (per capita) for rural households (all income groups)

The carbon footprint due to travel and cellphone usage is highest for higher income groups in rural areas. Whereas cooking fuel and food are the major contributors for the low income households. Figure 2 shows the relative contribution of the various sources to the total carbon footprint for a typical household in rural area. It clearly shows that the contribution to the carbon footprint is highest (36%) due to cooking fuel (majorly wood and kerosene). Table 2 shows the contribution of LPG, kerosene and wood to the carbon footprint due to cooking fuels in rural areas across different income groups. It is observed that the contribution of LPG is highest for high income group, while the middle and low income groups have a substantial contribution from wood. Table 3 compares these cooking fuels in terms of their carbon footprint per unit of energy content and the efficiency of the cooking device used to burn the fuel. Wood, with relatively lower calorific value and efficiency, and higher carbon content, is the biggest contributor to the carbon footprint due to cooking fuel.

Table 2: Contribution to carbon footprint by different cooking fuel in rural areas

	Contribution of carbon footprint (kg of CO_{2e} per capita per year)		
Source	Annual Household Income < INR 30,000	Annual Household Income: INR 30,000-100,000	Annual Household Income > INR 100,000
LPG	14.9	20.1	66.5
Kerosene	25.6	17.7	4.1
Wood	244.7	310.9	154.7

Table 3: Comparison of CO_{2e} emissions due to different cooking fuels

Fuel type	kg of CO_{2e} per kg of fuel	Calorific Value (kJ/kg)	kg of CO_{2e} per GJ of energy content in fuel	Efficiency of the device used for cooking	kg of CO_{2e} per GJ of energy supplied
Wood	1.5	19080	83.7	10% (Witt, 2005)	837
Kerosene	2.5	35035	71.9	35% (Bhattacharya and Cropper, 2010)	205.4
LPG	2.9	43074	69.3	60% (Bhattacharya and Cropper, 2010)	115.5

3.2 Wood: Is it a CO_2 neutral fuel?

Biofuels are different from fossil fuels as they can act as the sources and sinks of CO_2. As the plants grow they function as a sink, drawing CO_2 out of atmosphere and incorporating carbon into the tissues of plant. When biofuels (e.g. firewood) are burnt, the CO_2 is emitted back into the atmosphere. By contrast, fossil fuel emits CO_2 but fossil fuels do not form fast enough to be considered as a sink. Thus it is typically assumed that biofuels have no net impact on atmospheric CO_2 levels, because they act as both source and sink. This assumption is valid only when the biomass is sustainably grown and harvested i.e. rate of regeneration of biomass matches that of its consumption.

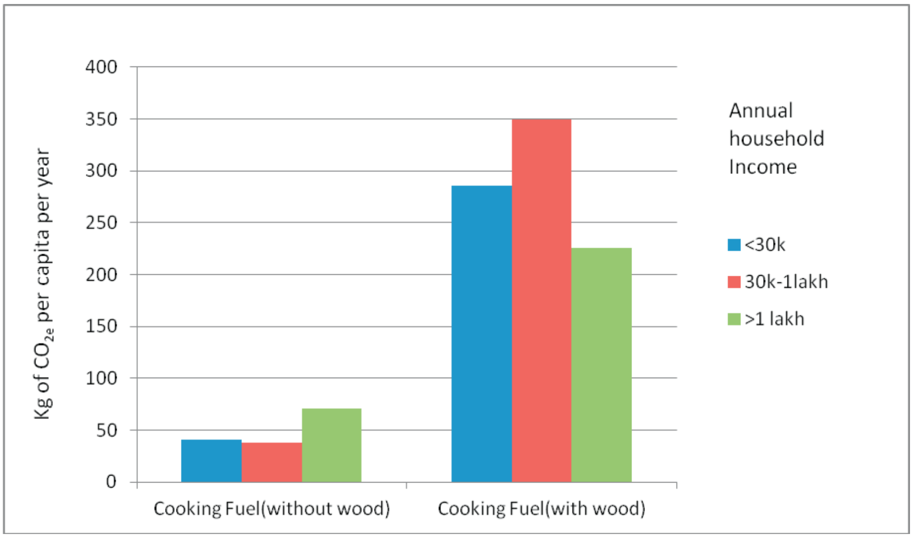

Figure 3: Comparison of carbon footprint due to cooking fuel in rural areas considering wood as CO_2 as neutral and non-CO_2 neutral

Among all the biofuels, wood is the most commonly used biofuel in India. Figure 3 gives a clear picture of the difference in carbon footprint due to the inclusion or exclusion of emissions due to wood from that of cooking fuel. There is a difference of approximately 250 kg of CO_{2e} per capita per year in rural areas depending on the assumption regarding sustainable harvesting of firewood.

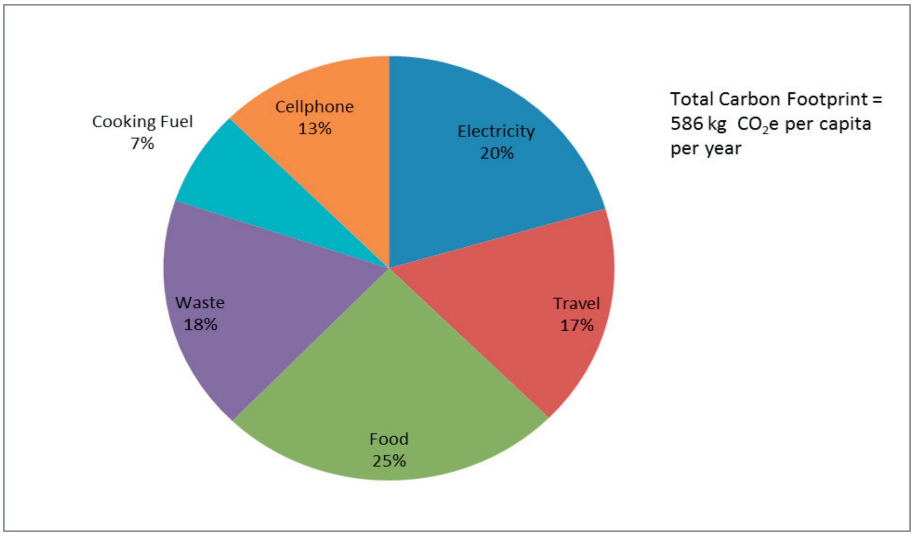

Figure 4: Break up of average carbon footprint (per capita) for rural households when wood is considered CO_2 neutral

Leaving emission due to wood in the final carbon footprint calculation significantly reduces the contribution of rural areas towards climate change. The actual carbon footprint may lie somewhere in the range 586-843 kg of CO_{2e} per capita per year.

Figure 4 shows the breakup of average carbon footprint (per capita) for rural households when wood is considered CO_2 neutral. It may be noted (by comparing to Figure 2), that the contribution of cooking fuel reduces from 36% to merely 7% in this case.

3.3 Urban Carbon Footprint:

In all, 46 households from various localities (Chaitanya Nagar, Mulund, Bhandup, Kalyan, Hiranandani) in Mumbai city were surveyed as part of this study. The average number of members in these households was 4, ranging from 2 to 9. From the survey done in the urban areas, it was observed that the electricity consumption (per month) in urban area ranges from 23kWh to 413kWh per capita depending on the income of the family. Most of the people have personal vehicles and a large number of them use public transport as well for commuting to their work places. The distance travelled is also significantly longer than that by the rural population. Significantly more travel by trains and airplanes has also been reported. Thus, the range of distance travelled (per year) varies from 400 km to 32500 km per capita. The diet of theurban people consists of much larger variety than that of rural people. LPG is the major cooking fuel. Cellphone usage per day varies from 2 minutes to 123 minutes per capita.

There is more variability in the socio-economic statuses in urban area compared to rural area because of wide distribution of income among the population. The income varies from as less as INR 30,000 to millions of Indian Rupees per annum. Based on the annual income of each household, they were divided into 3 groups:

a) < INR 400,000
b) INR. 400,000 to INR 1,500,000
c) > INR 1,500,000

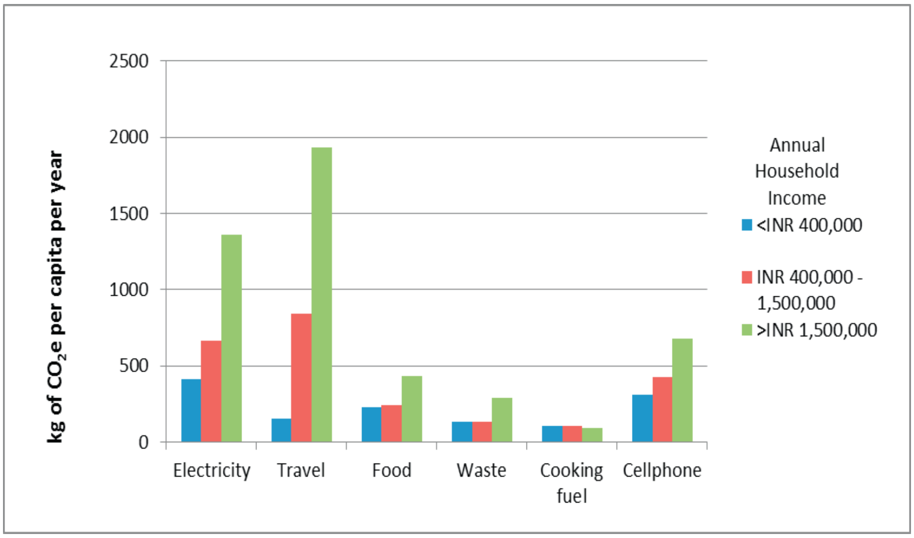

Figure 5: Contribution of various sources to urban carbon footprint (per capita) across various income groups

Figure 5 shows the variation in the contribution of various sources to the total carbon footprint across the 3 income groups for the urban households. Interestingly, contribution from of cooking fuel is very small (4%) and is almost same for all the income groups whereas for rural areas the cooking fuel is the highest contributor towards total emissions with a share of 36%.

Figure 6 shows the relative contribution of the various sources to the total carbon footprint of the urban households. It clearly shows that travel and electricity are the major contributors to the total carbon footprint in urban areas.

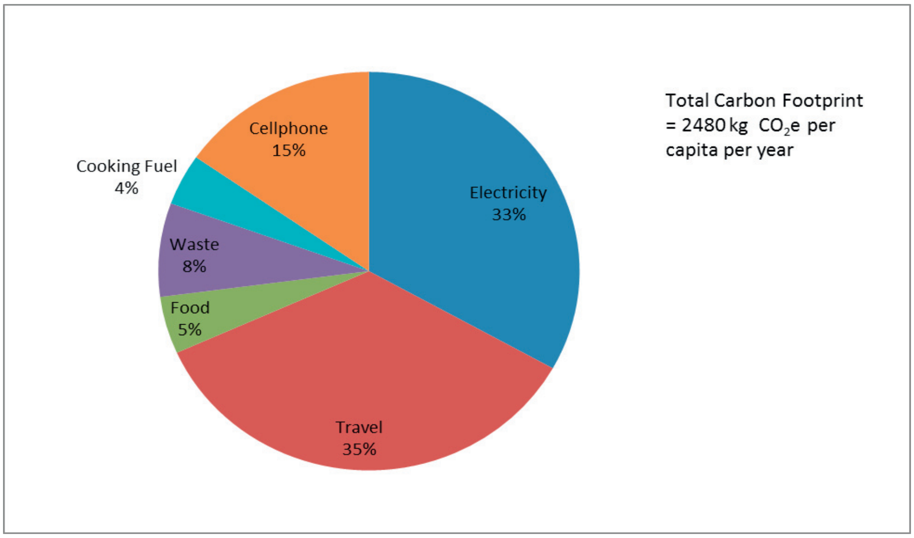

Figure 6: Breakup of the average carbon footprint (per capita) for urban households (all income groups)

3.4 Comparison of carbon footprint between Rural and Urban area:

From Figure 7 and Table 4, we can clearly see that the carbon footprint due to electricity, travel, cellphone and waste are much higher for urban areas. This is a clear reflection of the urban lifestyle that depends on electricity as the lifeline. Also, mobility and connectivity (through mobile phones) have become essential services in the urban areas. On other hand, carbon footprint due to the cooking fuels and food are higher in rural areas. This can be easily explained by the fact that the usage of less efficient cook-stoves with wood for cooking purpose is very common in rural areas whereas, it is negligible for urban areas. The food pattern on other hand can be explained by the lifestyle followed in these areas. The diet of rural people mainly consists of rice which has a high CO_{2e} emission factor compared to other food items. Whereas in urban areas people eat variety of food reducing the amount of rice consumed compared to rural areas. It should be noted that the emissions related to the food miles have not been accounted for in this analysis.

Table 4: Annual average per capita carbon footprint for Urban and Rural areas

Sources	**Annual average Carbon Footprint in rural household (kg CO_{2e} per capita per year)**	**Annual average Carbon Footprint in urban household (kg CO_{2e} per capita per year)**
Electricity	120	821
Travel	100	872
Food	145	115
Waste	105	188
Cooking Fuel	299	103
Cellphone	73	380
Total	**843**	**2,480**

Table 5 shows the variation of the carbon footprint observed across different socio-economic classes in both the rural and the urban areas. This is attributed to the fact that the cut-offs for the income groups are different and dependent on the area and there is a growing influence of urban lifestyle on affluent rural population.

Table 5: Comparison of carbon footprint across different socio-economic statuses for rural and urban areas (kg of CO_{2e} per capita per year)

Area	Low Income Group	Middle Income Group	High Income Group
Rural	729 (437-1529)	892 (560-1418)	1284 (665-2300)
Urban	1350 (524-1949)	2429 (633-4433)	4796 (85-9576)

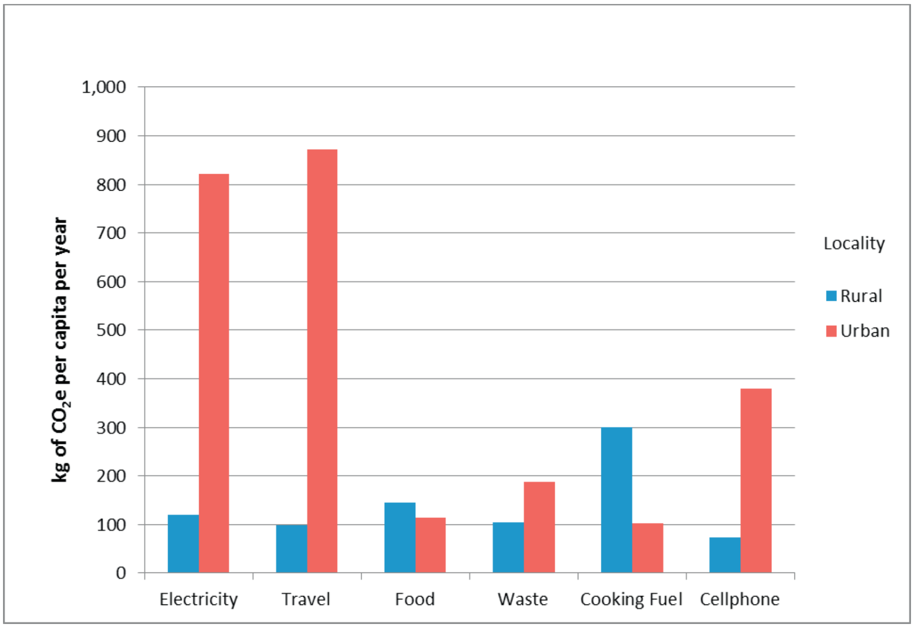

Figure 7: Contribution of various sources to carbon footprint in rural and urban areas

4. Conclusion and Discussions

4.1 Conclusions:

As it can be clearly seen, the carbon footprint of urban individuals is higher than that of the rural individuals. The average carbon footprint in rural areas is estimated to be 0.85 tonnes CO_{2e} per capita per year and in urban areas it is 2.5 tonnes CO_{2e} per capita per year. Among all the sources, cooking fuel (36%) is the biggest contributor to the rural carbon footprint whereas in the urban areas, electricity (33%) and travel (35%) are the major contributors. Long distance travel (including Air Travel) and high percentage of personal vehicle usage in the urban areas result in much higher carbon footprint as compared to the rural areas. The cooking fuel in rural areas is mostly wood which is inefficiently used in the traditional cook-stoves. So, cooking fuel is the single largest contributor to carbon footprint in rural areas whereas, it is very negligible in the urban carbon footprint. The amount of wood used can be substantially reduced by switching to the efficient cooking practices. The rural carbon footprint will go down by 250 kg of CO_{2e} per capita per year (~30%) if we assume the firewood to be CO_2 neutral. The carbon footprint per capita due to the cell-phone usage is much higher in urban areas and thus it forms a significant part of the carbon footprint in case of the urban areas as compared to the rural areas where the cell-phone usage is limited.

4.2 Solutions:

It is a well-known fact that India's carbon footprint has rose significantly over the past few years owing to the economic growth of the country. The huge population of the country though has kept the per capita carbon footprint within respected limits.

From the project, it is amply evident that people placed at the lower rung of the socio economic pyramid are helping in reducing the adverse impact on the nation's overall carbon emissions by those higher up. This can be solved in five ways

1. Adopting more sustainable ways of living in urban areas for example greater use of public transport, travelling when necessary, avoiding wastage of electricity etc.
2. Adopting energy efficient ways of cooking in rural areas which leads to reduced burning of wood etc.
3. Focusing on energy generation from renewable energy and then distributing it locally where possible, this will have a huge impact on meeting the needs of rural area in an environment friendly manner. This will lead to economic growth in rural areas and thus reduce the burden on urban areas to support the growth owing to less environmental exploitation in the urban areas.
4. Adopting more energy efficient devices like better fuel economy vehicles, led based electronic equipment etc.
5. India's per capita income (nominal) is close to 1600 USD. There needs to be a greater focus on innovating and developing highly energy efficient technologies or renewable energy based products which can be used by the masses without affecting their way of living.

4.3 Future Scope:

This study can be helpful in designing a transparent carbon calculator which will be specific for Indian situations and locations. Also for better results, the sample size of the survey could be increased by covering more number of households in various socio economic classes and also extending to covering more villages and cities.

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