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Rural and Urban Household Carbon Footprint: A Comparative Study, West Bengal, India.

Huella de carbono de los hogares rurales y urbanos: un estudio comparativo, Bengala Occidental, India

Dr. Nanda Dulal Hazra
Assistant Professor of Commerce, Tamralipta Mahavidyalaya,West Bengal,India
e-mail-nanda.hazra@rediffmail.com

ABSTRACT

Household emission is a significant contributor to total emission in the atmosphere. Household emission is measured in terms of Per Capita Carbon Footprint. Carbon Footprint can be defined as the total amount of greenhouse gases produced directly and indirectly by any individual or organization from its activities and it is expressed in equivalent tons of carbon dioxide (CO2e). From the latest report of JRC, 2020 per capita global average of CO2 emission in 2019 was 4.93 tCO2 tonne/Per Year and in India it was 1.9 tCO2 tonne/Per Year. In this backdrop the objectives of the article are: i) to measure the activity wise household carbon footprint of the sample households, and ii) to compare the activity wise carbon footprint of rural and urban households during the study period. Household Per Capita Carbon Footprint has been calculated using the emission factors of different components. From the study it is observed that maximum amount of emission generates from cooking activities for rural households and from food activities for urban households. Per Capita Carbon Footprint of rural household is 0.6071 tCO2e tonne/Per Year and 0.5119 tCO2e tonne/Per Year for urban household.

Key words: Carbon footprint, household emission, global warming, fossil fuels, emission factor.

RESUMEN

Las emisiones de los hogares contribuyen significativamente a las emisiones totales en la atmósfera. Las emisiones de los hogares se miden en términos de huella de carbono per cápita. La Huella de Carbono se puede definir como la cantidad total de gases de efecto invernadero producidos directa o indirectamente por cualquier individuo u organización a partir de sus actividades y se expresa en toneladas equivalentes de dióxido de carbono (CO2e). Según el último informe del JRC, el promedio mundial per cápita de emisiones de CO2 en 2020 en 2019 fue de 4,93 tCO2 por año y en India fue de 1,9 tCO2 por año. En este contexto, los objetivos del artículo son: i) medir la huella de

carbono del hogar por actividad de los hogares de la muestra, y ii) comparar la huella de carbono por actividad de los hogares rurales y urbanos durante el período de estudio. La Huella de Carbono Per Cápita de los Hogares se ha calculado utilizando los factores de emisión de diferentes componentes. Del estudio se observa que la máxima cantidad de emisión se genera a partir de las actividades de cocina para los hogares rurales y de las actividades alimentarias para los hogares urbanos. La huella de carbono per cápita de los hogares rurales es de 0,6071 tCO_2e ton/por año y de 0,5119 tCO_2e ton/por año para los hogares urbanos.

Palabras clave: Huella de carbono, emisión domiciliaria, calentamiento global, combustibles fósiles, factor de emisión.

INTRODUCTION

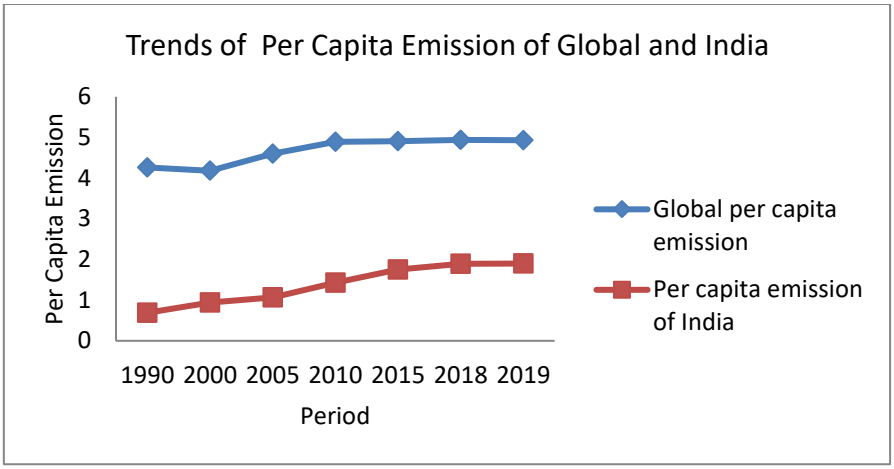
Global warming has different unfavourable effects on the living things in the planet. One of the main reasons of global warming is the overconcentration of CO_2 in the atmosphere. From the previous different studies it is reported that about 40 % of the total CO_2 emission comes from the household sector and the balance comes from the other sectors. Household emission is measured in terms of Per Capita Carbon Footprint. Carbon Footprint can be defined as the total amount of greenhouse gases produced directly and indirectly by any individual or organization from its activities and it is expressed in equivalent tons of carbon dioxide (CO_2e). Again it is also observed from the different studies conducted in abroad and India that there is a significant difference in per capita carbon footprint of rural and urban household. From the latest report of JRC it is observed that per capita global average of CO_2 emission in 2019 was 4.93 tCO_2 tonne/Per Year and in India it was 1.9 tCO_2 tonne/Per Year. Table no.1 and two line charts (Chart no.1 and 2) show the trends of total CO_2, Per Capita CO_2 and per GDP emission of globe and India.

Table no. 1: Trends of total CO_2, Per Capita CO_2 and CO_2 of per GDP emission of Globe and India

	1990	2000	2005	2010	2015	2018	2019
Globe Per Capita (tCO_2 tonne/Per Year	4.26	4.18	4.60	4.89	4.91	4.94	4.93
India	0.69	0.94	1.07	1.43	1.75	1.89	1.90
Total CO2 M tCO_2 tonne/year Globe	22,683.30	25,699.80	30,051.44	33,971.15	36,247.49	37,668.11	38,016.57
India	599.82	993.97	1,219.35	1,761.40	2,292.96	2,556.55	2,597.36
CO2 Per GDP emission Global (ton CO2/1K$) Year	0.44	0.38	0.37	0.35	0.32	0.30	0.29
India	0.38	0.37	0.33	0.34	0.32	0.29	0.28

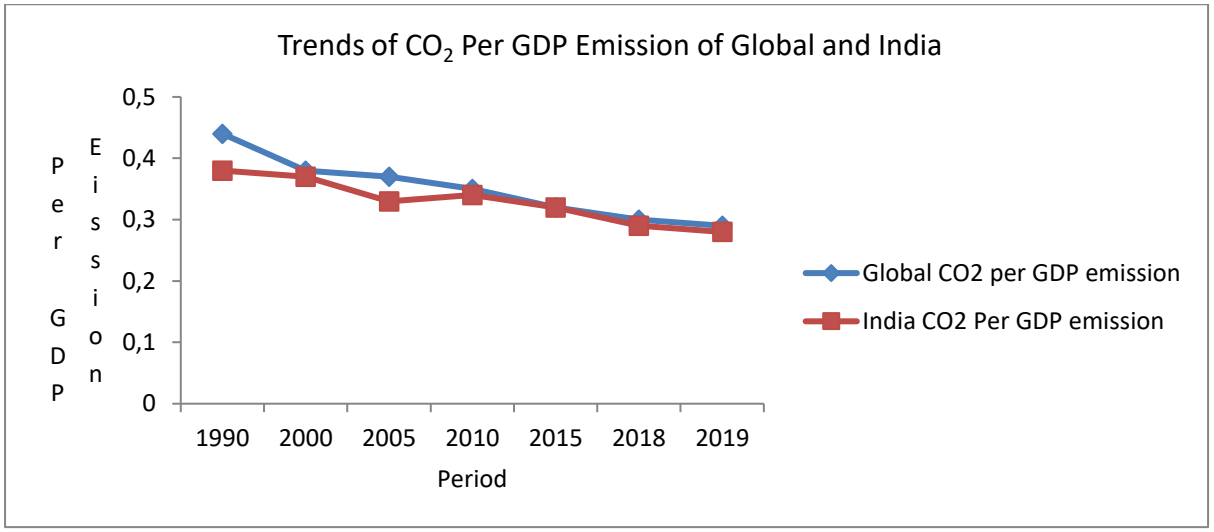
Source: Report on Fossil CO_2 emissions of all world countries, 2020 (www. edgar.jrc.ec)

Chart 1: Trends of Per Capita Emission of Globe and India over the years



Source: Based on table no. 1 data

Chart 2: Trends of CO_2 per GDP Emission of Globe and India over the years



Source: Based on table no. 1

Table no.1 and graph no.1 and 2 show that per capita CO_2 emission across the globe shows an increasing trend except the year 2000 and 2019. But, in case of India it is showing continuous increasing trend and the rate of growth for 1990 to 2019 is about 175%. In case of across the globe the rate of growth for 1990 to 2019 is about only 17%. In 2019 total CO_2 production percentage of India in Globe is about 6.83% and the percentage of growth for 1990 to 2019 is about 333%. Growth rate of total CO_2 production across the globe for 1990 to 2019 is about 67.6%. CO_2 per GDP emission for

the Globe and India show that it is decreasing from time to time and in 2019 it is more or less are same for globe and India.

Table no. 2 : Top CO_2 emitting countries and their Global share and its trends

Top emitting countries	Global Share	Change between 2018 and 2019	Average Annual % Change since 2015
China	30.3%	3.4%	2%
United States	13.4%	-2.6%	-0.7%
EU27+UK	8.7%	-3.8%	-1.4%
India	6.8%	1.6%	3.2%
Russia	4.7%	-0.8%	0.9%
Japan	3%	-2.1%	-1.5%

Source: JRC, 2020

Table no. 2 shows that in 2019, China, the United States, India, the EU27+UK, Russia and Japan - the world's largest CO_2 emitters - together emitted 67% of total global fossil CO_2. Emissions from these five countries and the EU28 show different changes in 2019 compared to 2018, the largest relative increase is found for China (+3.4%), followed by India (+1.6%). On the contrary, the EU27+UK (-3.8%), the United States (-2.6%), Japan (-2.1%) and Russia (-0.8%) reduced their fossil CO_2 emissions. So, the rate of increase in per capita emission and increase rate in total CO_2 emission of India is very alarming and needs immediate steps to cap it.

REVIEW OF LITERATURE

Raaij &Verhallen (1983): The objectives of their study was to identify the factors which had direct impact in home energy consumption and they found that Energy consumption and energy savings in the home were determined by the technical and architectural characteristics of the house and its heating/cooling system, on one hand and the behaviour of the resident, on the other hand. Other relevant house characteristics impacting energy consumption were the number of rooms in use, orientation towards sun and wind (ventilation), etc. Household behaviour in purchase-maintenance and usage related energy behaviour determined the energy use in the home.

Carbon Trust (2006): the objective of the study was to identify the impact of household emission in UKs total emission. They concluded that Households' direct energy consumption (domestic heating, private transport, and electricity for appliances) currently accounted for approximately 40 per cent of the UK's carbon emissions.

Kaveri Patil and Aparajita Chattopadhyay (2013): The objectives of the study were to identify the pattern of fuel consumption for cooking and lighting in India, to identify the main factors for choosing such fuel pattern and its associated CO_2 emission. They found that households in the rural areas mainly depended on firewood and chips (76%), dung cake (6%), LPG (12%), and kerosene (0.79%) for their cooking fuels. On the other hand, households in the urban areas mostly used LPG for cooking fuel and it was about 64.6%, followed by biomass 19%, and kerosene 6.4%. Monthly per capita fuel consumption in the rural areas was much higher than that in the urban areas. Income, location, and education level of the head of the family had direct relationship with the choice of the fuel used.

Sankesha P. Bhoyar et al. (2013): The objective of their study was to identify the effects of lifestyle, geographical location, and socio economic classes of the people on their carbon footprint. For this, they collected the data both in rural and urban areas and considered the direct emission of the households in the study area. Applying the emission factors they calculated the carbon footprints of the households and concluded that there was a significant difference in carbon footprints between rural and urban people and also among the different socio economic classes.

Sudhakar Jain and Anil Kumar (2016): The objectives of their study were to identify the relationship between rural and urban households' income with the households' energy consumption and the ways to reduce the indirect and direct energy consumption. They found that out of total energy consumption at the household level, 53% was of indirect nature. Energy consumption in different consumption categories varied largely and major consumption categories were food, durable goods, and miscellaneous (like recreation).They concluded that it was possible to reduce the indirect energy consumption by changing consumption pattern.

Objectives of the study:

The objectives of the study are: 1) to measure the activity wise household carbon footprint of the sample households, and 2) to compare the activity wise carbon footprint of rural and urban households during the study period.

Hypotheses of the study:

Considering the above objectives of the study following hypotheses have been formulated in Null-Alternate form:

~~The hypotheses of the study:~~

1. Null Hypothesis (H_{01}): All the selected household activities (food, electrification, cooking and transportation do not have the same impact on Per Capita carbon footprint of the household.

Alternative Hypothesis (H_{11}): All the selected household activities (food, electrification, cooking and transportation do have the same impact on Per Capita carbon footprint of the household.

2. Null Hypothesis (H_{02}): Activity wise Per capita carbon footprints of the households in rural areas do not differ significantly from those in urban areas.

Alternative Hypothesis (H_{12}): Activity wise Per capita carbon footprints of the households in rural areas differ significantly from those in urban areas.

DATABASE AND RESEARCH METHODOLOGY:

Study area: ~~it has~~ I have chosen Joteghanashyam village of Paschim Medinipur district, West Bengal, India and 45 NO. Ward of Howrah Municipal Corporation of Howrah district of West Bengal, India as the study area, purposively on the basis of convenience.

Study period: The study period of the research work spreads over six months from 10.08.2019 to 09.02.2020. Basically the primary data required for the research work have been collected over the stated period but the secondary data used for the study relates to different periods.

Sample design and size of sample: In this study purposive sampling method has been used to select the study area but random sampling technique has been considered to reach the ultimate sample household. Direct interview and proxy interview methods using the structured questionnaire have been used to collect the data from the households. In this study households of the village and ward from the municipality have been considered as rural households and urban households respectively. Total 50 households (approx. 10% of the total households) each from the rural area and urban area have been studied. In this way total 100 households have been included in the sample.

Sources of data

i) Sources of primary data: Primary data have been collected from the households of the study areas on the basis of a structured questionnaire and the households are selected on the basis of random sampling. Data regarding the following aspects have been collected from the households: Households' description, Family description, Energy profile of households, Food activities, Clothing habits etc.

ii) Sources of secondary data: Secondary data used in the research work have been basically collected from the, National Sample Survey Organization (NSSO), United Nations Framework Convention on Climate Change (UNFCCC), Department for the Environment, Food and Rural Affairs (DEFRA), Intergovernmental Panel on Climate change (IPCC), and JRC Report, 2020.

Methodology: Emission factors available from different reputed and authenticated sources have been used to calculate the emission from different activities of the household both for rural and urban households. Simple statistical tools like mean, percentage, growth rate and Z-test have been used to analyse the data.

Z-test is the statistical test, used to analyse whether two population means are different or not when the variances are known and the sample size is large. However, if population variance is unknown and the sample size is large we can replace the population variance by sample variance.

In this study I have used the two sample Z test to determine whether there are any significant differences in activity wise average per capita carbon footprint of rural and urban households. In this study the sample size is 50 households each from rural and urban households which are considered as large sample. So, to compare the mean I have used Z test in place of t test. We can calculate the value of Z using the below formula-

$$z = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

In Z test we can reject the null hypothesis comparing either the p value with the level of significance (α) or comparing the calculated value of Z with the critical value of Z considering the level of significance (α). We can reject the null hypothesis when the *p*-value is smaller than the level of significance (α) or when the calculated value of $|Z|$is more than the critical value.

In this study I have performed two tailed joint mean test considering the level of significance (α) at 5%.

FINDINGS AND ANALYSIS

Table no. 3: Comparative activity wise Per Capita Carbon Footprint (tCO_2e tonne) of the sample rural and urban household

RURAL HOUSEHOLD					URBAN HOUSEHOLD				
PCCF_Elec	PCCF_Food	PCCF_Cook	PCCF_Trans	PCCF Total	PCCF_Elec	PCCF_Food	PCCF_Cook	PCCF_Trans	PCCF Total
0.0468	0.1229	0.2957	0.1416	0.6071	0.1401	0.1529	0.0810	0.1379	0.5119
8%	20%	49%	23%	100%	27%	30%	16%	27%	100%
India*	1.9				1.9				
World*	4.93				4.93				

Source: Own Sample Survey

*www. edgar.jrc.ec (2020)

Table no. 3 shows that comparative activity wise per capita carbon footprint of rural and urban households. From the table it is observed that maximum amount of emission of rural households comes from cooking activities (49%) followed by transportation (23%), food (20%) and electricity (8%). It is observed that maximum amount of emission comes from cooking activities because of maximum use of traditional cooking fuels (e.g. cow dung cake, wood, kerosene) for cooking food. Maximum numbers of households still not have LPG connection and very low use of LPG which households have LPG connection. The reason of high amount of emission from the transportation activities is due to more dependency on private transport (mostly use of motor bike in rural areas). In case of use of more private transport sharing of emission is not possible. But, in case of public transport (like bus services, train services etc.) sharing of emission is possible.

In case of urban households maximum amount of emission comes from food (30%) followed by jointly from electricity and transportation activities (27%) and cooking (16%) activities. In food category maximum amount of emission comes from consumption of non-vegetarian food items (like chicken, mutton etc.) in the urban area. In urban areas households are more dependent on electronic equipment's which consume more electricity and generate emission. In the study area households are mostly dependent on motor bike and app based private car for transportation. For this sharing of emission is not available in transportation section in urban area also. The reason of low amount of carbon emission from cooking activities is the maximum use of modern or clean cooking fuel (mostly LPG).

Therefore, I accept the null hypothesis (H_{01}) and may conclude that all the selected household activities (food, electrification, cooking and transportation) do not have the same impact on Per Capita carbon footprint of the household.

Per capita carbon footprint of the rural households is only 0.6071 tCO_2 tonne/Per Year and for the urban household is 0.5119 tCO_2 tonne/Per Year. In 2019 as per JRC report Per capita carbon footprint of India are 1.9 tCO_2 tonne/Per Year whereas global average per capita carbon footprint is 4.93 tCO_2 tonne/Per Year. So, per capita carbon footprint of the sample households are far low than the India and the world average.

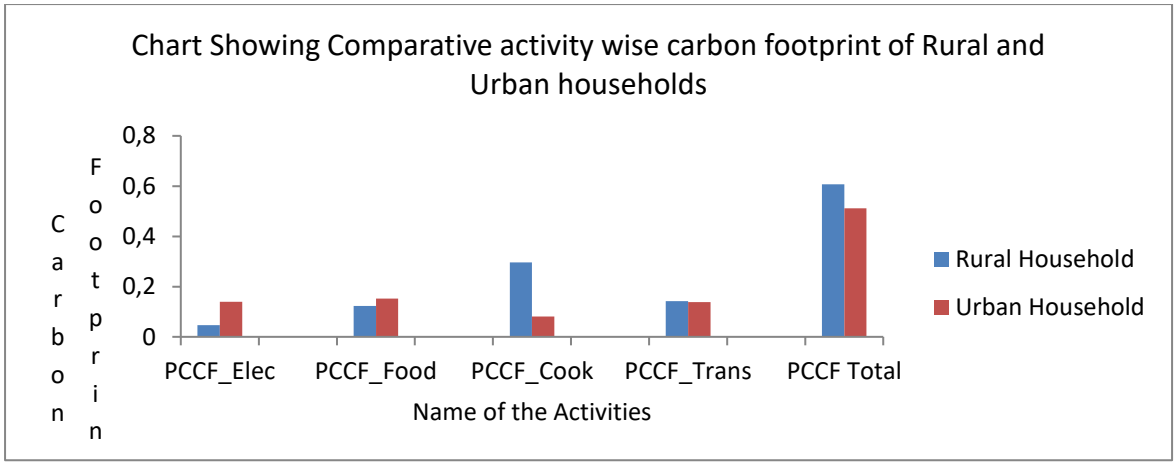


Chart No.3: Comparative activity wise carbon footprint of rural and urban households

Source: Based on table no.3 data

Table no. 4: Z test results for comparability of mean activity wise carbon footprint of rural and urban households

	Mean		Variance		Z	P(two-tail) value	Z critical value	Remarks
	Rural	Urban	Rural	Urban				
PCCF_Elec	0.0468	0.1401	0.00039	0.03231	-3.6482	0.00026	1.96	Reject H_{02}
PCCF_Food	0.1229	0.1529	0.00068	0.00120	-4.889	0.0087	1.96	Reject H_{02}
PCCF_Cook	0.2957	0.0810	0.01286	.00071	13.03	0.0001	1.96	Reject H_{02}
PCCF_Trns.	0.1416	0.1379	0.0134	0.0247	0.1356	0.8921	1.96	Accept H_{02}
PCCF_Total	0.6071	0.5119	0.06481	0.2117	-4.8481	0.00246	1.96	Reject H_{02}

Source: Based on table no.3 data

Z test has been used to determine whether there is any statistically significant difference in activity wise and total per capita carbon footprint between the rural households and urban households. Test results show that there are statistically significant differences between the rural and urban households so far as per capita carbon footprint from electricity activity, food activity, cooking activity and total carbon footprint are concerned. In respect of per capita carbon footprint from transportation activities there is no statistically significant difference between the rural and urban households.

Therefore, I reject the H_{O2} (except in case of transportation activity) and may conclude that activity wise per capita carbon footprints (except in case of transportation activity) of the households in rural area differ significantly from those in urban area.

As conclusion, Carbon footprint is the indicator of household emission. To reduce the emission from the atmosphere it is very important to reduce the carbon footprint at household level. In 2019 per capita global average of CO_2 emission was 4.93 tCO_2 tonne/Per Year and in India it was 1.9 tCO_2 tonne/Per Year. So, per capita carbon footprint of India is far low than others different countries as well as lower than the global average. In the study area it is observed that per capita carbon footprint of the urban household (0.5119 tCO_2 tonne/Per Year) is lower than the rural household (0.6071 tCO_2 tonne/Per Year). It is happen due to high amount of carbon footprint generating from cooking activities of the rural household due to maximum dependency on traditional cooking fuels which have high emission potential for cooking. So, there is a huge scope for reduction of per capita carbon footprint from cooking activities for rural household by fuel switching. The study also reveals that there is a significant difference in per capita carbon footprint between rural household and urban household so far as electricity consumption, food activities, cooking activities and total per capita carbon footprint are concerned.

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Emission factors of different items and their sources

Items	GWP (CO_2 E)
Rice	1221.3g/kg (Pathak et al, 2010)
Wheat	119.5g/kg (Pathak et al, 2010)
Pulse	306.8g/kg (Pathak et al, 2010)
Potato	24.9g/kg (Pathak et al, 2010)
Poultry meat	846.5g/kg (Pathak et al, 2010)
Mutton	12062.7g/kg (Pathak et al, 2010)
Egg	588.4g/kg (Pathak et al, 2010)
Fish	718.3g/kg (Pathak et al, 2010)
Milk	729.2g/kg (Pathak et al, 2010)
Fruits and vegetables	97g CO_2e/kg (Sankesha p. Bhoyar et al, 2014
Petrol	2207 g CO_2e per ltrb/0.24234 kg CO_2e/km (DEFRA, 2012)

Diesel	2650 g CO_2e per ltrb/0.22428 kg CO_{2e}/km (DEFRA, 2012)
Kerosene	2519 g CO_2e per ltr (IPCC)
LPG	2985 g CO_2e per kg 9 IPCC)
Wood	1597 g CO_2e per kg (IPCC)
Travel by train long	41.5 g CO_2e per km (IPCC)
Travel by train local	31.7 g CO_2e per km (IPCC)
Bus	135.52 g CO_2e/km (DEFRA, 2012)
Car	242.34 g CO_2e/km (DEFRA, 2012)
Bike	142.38 g CO_2e/km (DEFRA, 2012)
Electricity	820 g per KWH(Central Electricity Authority, 2011)
Cow dung cake	1070 g per kg (Greenpeace, India)
Coal	2060 g per kg (Greenpeace, India)

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