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Determinants of Household CO_2 Emissions in India: A State-Level Analysis of Energy Use

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ABSTRACT

This study analyzes state-level household CO_2 emissions in India from electricity use, personal vehicles, and cooking fuel during 2018–19. Covering 22 major states that represent over 95% of the population, results show that electricity accounts for nearly 90% of emissions, while cooking fuel and personal vehicles contribute about 5% each. Maharashtra, Uttar Pradesh, and Madhya Pradesh lead in electricity-related emissions, whereas Maharashtra, Uttar Pradesh, and Tamil Nadu rank highest in vehicle and LPG emissions. Regression analysis indicates that population and per capita GSDP are positively linked to emissions, while population density has a significant negative effect. These findings suggest that income growth drives higher household emissions, but dense settlement patterns can mitigate them. The study emphasizes the need for decentralized, state-specific climate strategies focusing on clean cooking fuels and efficient energy use to support sustainable and equitable low-carbon development in India.

Introduction

India, as one of the world's fastest-growing economies, presents a unique combination of demographic, geographic, and socio-economic diversity. Its vast territorial expanse encompasses a wide range of climatic zones, settlement patterns, and income levels, making the design of a uniform national climate strategy particularly challenging. In such a heterogeneous context, environmental and energy policies must account for substantial inter-state variations in resource use, infrastructure, and household behaviour. This diversity underscores the need for decentralized, state-specific assessments of energy consumption and associated carbon emissions. Understanding these differences is critical, especially as India intensifies efforts to balance rapid economic development with its long-term commitments to climate mitigation.

Households play a significant role in shaping India's carbon footprint. Residential electricity consumption has risen sharply over the last decade, driven by increasing electrification, appliance ownership, and improvements in living standards. Nearly universal household electrification—achieved by 2019 except for isolated pockets in Left-Wing Extremism–affected regions—combined with rising incomes has pushed electricity demand from 238,000 GWh in 2015–16 to over 310,000 GWh in 2019–20. While space heating remains limited due to India's predominantly tropical climate, electricity use for lighting, cooling, and household appliances has expanded substantially. As energy access improves further, household electricity demand is expected to continue rising, increasing its contribution to domestic CO_2 emissions.

Transport-related household emissions are also shaped by India's distinct mobility patterns. Private vehicles constitute more than 90 percent of the country's registered fleet, with two-wheelers dominating non-transport categories. The low share of public buses—only 6 percent of transport vehicles—reflects the inadequacy of mass transit systems and reinforces households' dependence on private mobility. States such as Maharashtra, Uttar Pradesh, Tamil Nadu, Gujarat, and Karnataka together account for nearly half of all registered vehicles and a substantial share of national petrol consumption. These patterns indicate that personal mobility is a major and growing source of household emissions.

Cooking fuel use forms another key component of domestic energy consumption. While LPG remains the dominant clean fuel, its rising adoption has significant implications for emissions. Domestic consumption accounts for over 87 percent of total LPG use, and the number of domestic LPG consumers has nearly doubled between 2010–11 and 2019–20. However, inter-state disparities persist, with certain states continuing to rely heavily on traditional biomass despite nationwide expansion of LPG access. The 22 states included in this study account for 97 percent of total LPG consumption, reflecting their central importance in shaping national cooking-fuel-related emissions.

Given these diverse patterns of electricity, transport, and cooking fuel consumption, a state-level analysis becomes essential for identifying the structural and behavioural drivers of household CO_2 emissions. Such an approach can support more effective, context-sensitive climate policy and guide equitable low-carbon transitions across India's varied socio-economic landscape.

Objectives, Data Sources and Methods

Objectives

The objective of this chapter is to (a) assess the extent of residential electricity and other fuel consumption sources and consequent CO_2 emissions due to domestic consumption at state level in India, (b) find out the impact of factors such as population, per capita GSDP and population density impacting on household emissions across major 22 states for the year 2018-19.

Data Source

The various data sources referred to for this analysis are shown in Table 1.

Table 1: Data Sources

Sl. No.	Data	Source
1.	State-wise end use sale of electricity to ultimate consumer in 2018-19	RTI to CEA[1]
2.	State-wise combined emission factor for end-use consumption	cBalance Solutions Pvt. Ltd: Electricity GHG Inventory Report 2009-10
3.	State wise data on registered motor vehicles	Road Transport Year Book 2016-17
4.	State wise population and other demographic variables data for the year 2018-19	Census 2011 population projections[2]
5.	GSDP 2018-19 at constant prices (2011-12)	National Statistical Office (MoSPI)
6.	LPG and Motor Spirit consumption data	India PNG statistics 2018-19 (Ministry of Petroleum and Natural Gas).

Estimation Method

Energy consumption and subsequent emission of CO2 for domestic sector is defined as the combination of total electricity and cooking gas consumption, and use of vehicles. Further, the use of energy under above mentioned three sources and subsequent release of emission are estimated in the following sub-sections using Tier -2 methodology of IPCC (2006) as below.

$$Emissions_{GHG,fuel} = Fuel\ Consumption\ _{fuel} * Country\ Specific\ Emission\ Factor\ _{GHG,fuel}$$

These 22 states together accounted for approximately 98% of total end-use electricity consumption by ultimate consumers in 2018–19, and for 96% of total transport vehicles and 98% of total non-transport vehicles in 2016–17 (Road Transport Year Book, 2016–17).

In 2018–19, the end-use consumption of High Speed Diesel (HSD) for road transport constituted only 3.3% of its total national consumption, while Light Diesel Oil (LDO) accounted for merely 0.7% (India PNG Statistics, 2018–19). These figures indicate that petrol remains the predominant energy source for domestic vehicles. Accordingly, for estimating CO_2 emissions from personal vehicles, it is assumed—that the entire quantity of petrol consumed at the state level is attributable to transport use. Furthermore, the state-wise share of non-transport vehicles is employed as a proxy for the share of petrol consumed by personal vehicles.

India PNG Statistics (2018–19) report that household consumption constituted 87.2% of total LPG usage in 2018–19. In line with this, the analysis assumes that in each state, 87.2% of total LPG consumption is attributable to domestic use.

Table 2: Emission Estimation Methods

[1] RTI filed with CEA on 3 December 2020, Registration No. CEATY/R/E/20/00341
[2] POPULATION PROJECTIONS FOR INDIA AND STATES 2011 – 2036, REPORT OF THE TECHNICAL GROUP ON POPULATION PROJECTIONS November, 2019, NATIONAL COMMISSION ON POPULATION MINISTRY OF HEALTH & FAMILY WELFARE

Emissions	*Calculation Method*
$\boldsymbol{CO2\ emissions\ from\ Domestic\ Electricity\ Consumption\ (Kg\ CO2)}$	$\boldsymbol{\Sigma\ (Electrical\ energy\ sales\ to\ ultimate\ consumers\ state-wise\ utilities\ \&\ non-utilities\ \ in\ kWh * Corresponding\ State's\ Combined\ Emission\ Factor\ for\ End-User\ Consumption\ (kgCO2e/kWh))}$
Emissions from Personal Vehicle Use	Step 1: Petrol consumption in TMT[3] is converted to litres using, 1 litre petrol = 0.71 kg of petrol Step 2: $\mathbf{CO2\ emissions\ form\ personal\ vehicles\ (Kg\ CO2) = [Petrol\ consumption\ in\ litres * Emission\ Factor\ of\ Petrol * Sate-wise\ share\ of\ non-transport\ vehicles\ (in\ \%)]/100}$
$\mathbf{CO2\ emissions\ from\ LPG\ consumption\ (Kg\ CO2)}$	$\mathbf{\Sigma\ (LPG\ consumption\ (kg) * LPG\ Emission\ Factor * 0.87)}$

Regression Model

The following equations have been estimated in this study as shown in Table 3:

Table 3: Regression Models

Equation 1	$\boldsymbol{CO2\ Emission\ from\ Electricity\ Consumption = population + per\ capita\ GSDP + population\ density + e}$
Equation 2	$\boldsymbol{CO2\ emissions\ from\ Personal\ Vehicle\ Use = population + per\ capita\ GSDP + population\ density + e}$
Equation 3	$\boldsymbol{CO2\ emissions\ from\ LPG\ use\ for\ Cooking = population + per\ capita\ GSDP + population\ density + e}$

Analysis of Results and Discussion

Demographic Profile of the States

Table 4 depicts a glance of the demographic profile of major 22 states of India. These states account for more than 95 percent of India's population.

Table 4: Demographic Profile of Major States in India

Sl. No.	States	Population ('000) (2018-19)	Population density (sq. Km.)	Urban (%)
1	Andhra Pradesh	52221	329	34.1
2	Assam	34293	447	15.1
3	Bihar	119520	1307	12.0
4	Chhattisgarh	28724	218	25.8
5	Delhi	19814	13871	99.1
6	Gujarat	67936	356	46.7

[3] Thousand Metric Tons

7	Haryana	28672	667	39.7
8	Himanchal Pradesh	7300	133	10.2
9	Jammu and Kashmir	13203	82	29.5
10	Jharkhand	37403	483	25.5
11	Karnataka	65798	349	42.5
12	Kerala	35125	913	66.5
13	Madhya Pradesh	82232	274	28.6
14	Maharashtra	122153	404	47.4
15	Odisha	43671	283	18.1
16	Punjab	29859	602	40.4
17	Rajasthan	77264	232	26.0
18	Tamil Nadu	75695	587	51.9
19	Telangana	37220	337	45.0
20	Uttar Pradesh	224979	958	23.5
21	Uttarakhand	11141	213	34.0
22	West Bengal	96906	1106	35.1

Source: Census 2011 projections

Table 5 shows that urban population and population density have high standard deviation, skewness and kurtosis. Highest urban population along with highest population density is observed in Delhi (99%), lowest urban population in Himanchal Pradesh (10%) and lowest population density in Jammu and Kashmir (now separate UTs) (Table 4). Rest of the variables do not show much variation and thus are not considered to be significantly affecting the energy consumption.

Table 5: Descriptive Statistics of Demographic features of India

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Population density	1097.8	380	13871	82	2871.2	4.27	19.54	317.94
Urban (%)	36.2	34.1	99.1	10.22	19.69	1.47	5.88	15.56

Source: Estimated from Census 2011 projections

CO2 Emissions by the States

Table 6 shows the state wise household emissions from electricity consumption, vehicle usage and LPG consumption. Maharashtra, Uttar Pradesh and Madhya Pradesh are the top three emitters in case of electricity consumption holding a share of 8% to 12% in total electricity emissions. While in case of personal vehicle emissions, Maharashtra, Uttar Pradesh and Tamil Nadu hold the top three positions, with their share lying between 8% and 12% of total personal vehicle emissions. In case of LPG emissions Uttar Pradesh, Maharashtra and Tamil Nadu top the list, with their shares lying between 8% and 14% of total LPG emissions (Table 6). In Bihar, share of LPG emissions (5%), personal vehicular emissions (2.8%) and emissions from electricity consumption (3.1%) is much lower than its population share (9.1%). Majority of Bihar's population is still dependent on fuel wood and other unclean sources of cooking fuel. According to the National Family Health Survey, Ministry of Health and Family Welfare, 2019-20, conducted in 17 states and five union territories, in five states Assam (42.1%), Bihar (37.8%), Meghalaya (33.7%), Nagaland (43%), and West Bengal (40.2%) less than 45% of households use clean fuel for cooking. Vehicle ownership rate (number of registered motor vehicles per 1000 population) was found to be lowest in Bihar (48.01) and highest in Delhi (519.62)[4].

Further, in our study electricity consumption accounted for nearly 90% of total emissions, while cooking fuel and personal vehicle constituted nearly 5% each of the total emissions in each state. Ahmad et al (2015) studied the emissions from domestic energy consumption in 60 largest cities in India and found that emissions from electricity usage account for about 66%, followed by emissions from cooking fuels (27%) and private transportation (7%).

4 Estimated using Road Transport year book 2016-17 and Census 2011 population projections. Vehicle Ownership Rate = (State-wise number of registered motor vehicles/State wise population projection 2016)*1000

Table 6: State wise Annual CO2 Emissions ('000 tonnes)

Sl. No.	States	From Electricity consumption		From Personal Vehicle Use		From LPG Use		Total Emissions	
		Value	% share	Value	% share	Value	% share	Value	% share
1	Andhra Pradesh	57600	4.0	3227.6	3.9	2985.5	4.6	63813.1	4.0
2	Assam	10500	0.7	1159.6	1.4	1092.9	1.7	12752.5	0.8
3	Bihar	44500	3.1	2306.4	2.8	3206.2	5.0	50012.6	3.2
4	Chhattisgarh	61300	4.3	1691.5	2.1	708.7	1.1	63700.2	4.0
5	Gujarat	112000	7.8	5740.1	7.0	2868.7	4.4	120608.8	7.6
6	Haryana	56000	3.9	2825.6	3.4	2089.8	3.2	60915.4	3.8
7	Himachal Pradesh	2380	0.2	608.0	0.7	428.4	0.7	3416.4	0.2
8	Jammu & Kashmir	7810	0.5	731.5	0.9	532.2	0.8	9073.7	0.6
9	Jharkhand	45000	3.1	1304.4	1.6	885.3	1.4	47189.7	3.0
10	Karnataka	52700	3.7	6211.0	7.5	4379.6	6.8	63290.6	4.0
11	Kerala	2900	0.2	4047.3	4.9	2567.5	4.0	9514.8	0.6
12	Madhya Pradesh	116000	8.1	4189.9	5.1	2583.1	4.0	122773	7.7
13	Maharashtra	176000	12.2	9799.4	11.9	7762.3	12.0	193561.7	12.2
14	Orissa	61800	4.3	2250.8	2.7	1425.3	2.2	65476.1	4.1
15	Punjab	50800	3.5	2393.6	2.9	2435.1	3.8	55628.7	3.5
16	Rajasthan	82000	5.7	4591.2	5.6	3356.7	5.2	89947.9	5.7
17	Tamil Nadu	111000	7.7	7689.3	9.3	5488.1	8.5	124177.4	7.8
18	Telangana	56100	3.9	3499.9	4.2	2500.0	3.9	62099.9	3.9
19	Uttarakhand	1500	0.1	918.4	1.1	747.7	1.2	3166.1	0.2
20	Uttar Pradesh	164000	11.4	9551.3	11.6	8219.2	12.7	181770.5	11.5
21	West Bengal	64800	4.5	2616.0	3.2	4387.4	6.8	71803.4	4.5
22	Delhi	30600	2.1	2720.4	3.3	2141.8	3.3	35462.2	2.2
	Total (All India)	1440000	100.0	82360.5	100.0	64661	100.0	1587021	100.0

Source: Self Estimated

Factors Determining CO2 Emissions in Domestic Sector in India

Multiple factors are affecting for domestic emission of CO2 at all India level, however, we could identify based on the availability of data such as total population, per capita GSDP and density of population as significant factors. In order to understand the impacts of these factors on CO2 emission, we have used multiple regression model and related steps are as follows.

Multicollinearity

The variance inflation factor (VIF) is used here to detect the severity of multicollinearity problem in the regression analysis. Generally, a VIF larger than 10 suggests that severe multicollinearity, which may influence the regression estimation results significantly (Wang et al 2013). In our results, VIF is found to be much less than 10 for all the variables, therefore, it is assured that there is no problem of multi-collinearity (Table 7).

Table 7: Results of VIF

Variable	VIF	1/VIF
Population	1.22	0.8165
Per Capita GSDP	1.84	0.5421
Population Density	1.57	0.6378
Mean VIF	1.55	

Source: Estimated from Census 2011 projections

Regression Results

Robust regression is performed in order to avoid the heteroscedasticity problem. Based on the estimation of results as shown in Table 8, all independent variables are found to be significant. While population and per capita GSDP has positive relation with CO2 emissions (from electricity consumption, personal vehicle use, LPG use for cooking and other purposes), population density is observed to have negative relation across the states. An increase in per capita GSDP by Rs.1 leads to an increase of total emissions by 334.53 tonne CO2, electricity consumption related emissions by 285.57 tonne CO2, personal vehicle emissions by 31.01 tonne CO2 and LPG emissions by 17.95 tonne CO2. An increase in population by 1 person leads to an increase of total emissions by 979.9 kg CO2, electricity consumption related emissions by 880.7 kg CO2, personal vehicle emissions by 53.9 kg CO2 and LPG emissions by 45.24 kg CO2. Since population density is observed to have a negative relation with CO2 emissions, an increase of 1 person per sq.km. leads to a decrease in total emissions by 4546.74 tonne CO2, electricity consumption related emissions by 4053.94 tonne CO2, personal vehicle emissions by 336.43 tonne CO2 and LPG emissions by 156.39 tonne CO2.

The results are in conformity with the literature. All the studies confirm a positive relation between income and emissions (Zhang et al 2015; Duarte et al 2010), as the increase in income leads to increased household consumption expenditure on transport, entertainment and other luxury comforts (Peters et al 2007). Some studies also suggest that as the household income increases, its direct emissions decline (due to decreased dependence on fossil fuels for cooking, lighting and heating), while its indirect emissions increase (Lyons et al 2012; Golley and Meng 2012). None of the sample households in our study was observed to be dependent on fossil fuels for lighting and cooking, therefore, such differentiation was not possible in this study.

Table 8: Regression Results

	Dependent variable	Independent Variables				R sq. Value
		Per Capita GSDP	Population Density	Population	Constant	
Eq. (1)	CO2 emissions from Domestic Electricity Consumption	285574.1 (1.78)***	-4053939 (-1.86)***	880.72 (5.93)*	$-2170*10^7$	67.8%
Eq. (2)	CO2 emissions from Personal Vehicle Use	31009.35 (5.46)*	-336430.8 (-3.99)*	53.94 (10.82)*	$-309*10^7$	84.9%
Eq. (3)	CO2 emissions from LPG use for Cooking	17949.1 (4.52)*	-156392.4 (-2.72)*	45.24 (10.36)*	$-192*10^7$	90%
Eq. (4)	Total CO2 emissions	334531 (2.02)**	-4546744 (-2.01)**	979.91 (6.27)*	$-2670*10^7$	70.96%

*Indicates significance at 1%, ** Indicates significance at 5%, *** Indicates significance at 10%; No. of observations= 22; Prob > F = 0.0000; (t-value))

Zheng et al (2011) observed a negative relationship between carbon emissions and population density due to low vehicle ownership rate in dense areas. Chen et al (2008) also suggested a negative relationship between population density and the domestic consumption of both electricity and natural gas in China. Ahmad et al (2015), using the data of 60 largest cities in India, found that urban population density is negatively correlated with emissions, except in the case of cooking fuel use. Further, the impact of population density was observed to be particularly significant in case of private vehicle emissions. The results of this study also suggest a negative relationship between population density and carbon emissions in case of electricity consumption, private vehicle use as well as total emissions. The negative relation observed between emissions and the use of LPG for cooking in our study may due to various reasons such as the underlying assumption of 87% of LPG consumed for domestic use in all the states. Also, the varying composition of rural-urban population and the corresponding fuel usage (fuel wood, LPG, green gas, etc.) in each state could impact the cooking fuel consumption and the consequent emissions.

Conclusion and Policy Recommendations

The analysis of household CO_2 emissions across 22 major Indian states shows clear differences in emission patterns shaped by demographics, economic conditions and household energy choices. Electricity consumption is the dominant contributor, accounting for nearly 90 percent of total household emissions, while LPG use and personal vehicle emissions contribute only about 5 percent each. States such as Maharashtra, Uttar Pradesh, Madhya Pradesh and Tamil Nadu emerge as the highest emitters because of their large populations and rising income levels, which drive higher energy demand. In contrast, states like Himachal Pradesh, Uttarakhand and several northeastern states display significantly lower emissions. Regression results confirm that population size and per capita GSDP are positively associated with emissions, indicating that economic growth increases households' energy-intensive consumption. Conversely, population density has a significant negative relationship with emissions, suggesting that dense urban environments may reduce transport-related energy use and encourage efficiencies in electricity consumption. States with low LPG penetration, particularly Bihar, Assam and West Bengal, show lower LPG emissions mainly due to continued reliance on traditional biomass, underscoring a critical developmental gap.

These findings highlight the need for a comprehensive, state-specific approach to reducing household emissions. Since electricity is the main source of emissions, policies should focus on promoting energy-efficient appliances, stricter building energy codes and wider adoption of rooftop solar systems. Enhancing access to clean cooking fuel is equally important; strengthening LPG distribution, improving refill affordability and raising awareness about the health benefits of clean fuels can accelerate the shift away from biomass. Encouraging compact urban development, expanding public transport and improving last-mile connectivity can reduce dependence on private vehicles, especially in high-emission states. At the same time, incentivising electric mobility and shared transport options can further curb household-level emissions. Behavioural interventions—such as promoting responsible electricity use, reducing wastage and encouraging sustainable lifestyle choices—should complement technological and infrastructural measures. Collectively, these strategies can help transition India's domestic sector toward a more energy-efficient and low-carbon future.

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