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Climate Change **12**

# Carbon Emissions due to Electricity Consumption in the Residential Sector

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Concentration of greenhouse gases (GHG) in the atmosphere has increased rapidly due to anthropogenic activities resulting in significant increase in the temperature of the earth causing global warming. Among the GHG's, carbon dioxide is the most dominant gas causing global warming which accounts for nearly 77% of global total $CO_2$ equivalent GHG emissions (IPCC 2007c). Carbon dioxide concentration in the atmosphere has been rising alarmingly in the post industrial revolution era and the current level is about 379 ppm (ppm = parts per million) compared to 280 ppm earlier (pre industrialisation). Concentration of greenhouse gases (GHG's) in the atmosphere has increased rapidly due to anthropogenic activities resulting in significant increase in the temperature of the earth. The energy radiated from the sun is absorbed by these gases making the lower part of the atmosphere warmer. The sources of greenhouse gases (GHG) come from various sectors including transportation, industrial processes, power generation for residential consumption, agriculture and deforestation. Sector wise analysis of annual GHG emission shows that electricity generation (21.3%), industrial processes (16.8%) and transportation fuel (14%) are the major sectors contributing primarily to GHG. In this backdrop, it is necessary to know the energy consumption structure to reduce carbon dioxide emission through shift in energy sources or end use efficiency improvements. Survey was conducted to know the energy consumption structure, also community and neighborhood of households of Bangalore. A total of 1967 households were surveyed from different wards of Bangalore. Survey data includes data about environment satisfaction, residential status, Building type, kind of facilities near the home and energy consumption behavior of households. Analysis was done according to ward wise and also for overall data. Analysis shows that more than 50% satisfied with overall environment, residential status of 70% household is local urban resident.80% household uses LPG for cooking and 11% use both LPG and

electricity. For water heating 40% uses electrical heater and only 24.76% uses solar water heater which is one of the source of reducing energy consumption and only 30% have installed solar appliances in home. Greater Quantification of emissions from domestic sector of Bangalore contribute about 4273.81 Gg (9.65% of total emissions).

**Keywords:** Global warming, carbon dioxide, energy consumption behavior, Household

## 1.0 Introduction

Global warming due to the increased concentrations of greenhouse gases (GHG's) in the atmosphere is causing climate patterns to change. Global warming repercussions include major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer. Climate change is one of the greatest threats facing the planet Earth and hence has dominated social, economic, environmental and political aspects of cities, states, and countries around the world. Carbon dioxide emissions from human activities are the major cause of global warming. Reduction in the carbon footprint is accepted worldwide to mitigate global warming. Carbon footprint refers to the total set of GHG emissions caused directly or indirectly by an individual, organization, event or product (UK Carbon Trust, 2008). This is measured by through the quantification of GHG emissions. Carbon dioxide ($CO_2$) is the primary greenhouse gas emitted through human activities. The main sources of $CO_2$ emissions are electricity, transportation and industry. One of the main human activity that emits $CO_2$ is the combustion of fossil fuels (coal, natural gas, and oil) for energy. Energy constitutes is an important source of many serious environmental problems due to the increase in emissions of GHG's with the exponential growth of energy sector to meet the demand of burgeoning population. In the wake of the residential energy consumption outpacing of industrial sectors in some developed countries post 1990's, the carbon emissions from residential sectors are emerging as new source of carbon emissions (Weber and Adriaan,2000; Bin and Dowlatabadi,2005; Druckman and Jackson, 2009). Cooking, water and space heating, pumping of water, transportation are the major energy activities in the residential sector

Conservation of energy and hence reductions in emissions, requires the changes in energy consumption behavior and implementation of low-carbon economic development. This necessitates the optimization of energy consumption structure, improvement of end-use energy efficiency and reduction of carbon emission intensity. Residential carbon emissions are due to the energy consumption in different activities such as cooking, hot water, heating etc. The main objective of the paper is to analyze the energy consumption patterns in the neighborhood and community of households in different wards of Bangalore. This also includes the study of household behavior regarding energy use as energy consumption is the outcome of type of implements, etc. Study was undertaken to assess the consumption patterns in different wards of Bangalore city.

## 2.0 Study Area

Greater Bangalore (77°37'19.54'' E and 12°59'09.76'' N), is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka. It is the fifth largest metropolis in India, with an area of 741 sq. km. Bangalore's city administrative jurisdiction was widened in 2006 by merging the existing area of Bangalore city spatial limits with 8 neighbouring Urban Local Bodies (ULBs), and 111 Villages of Bangalore Urban District (Ramachandra and Kumar, 2008). Thus, Bangalore has grown spatially more than ten times since 1949 (69 square kilometres) and is a part of both the Bangalore urban and rural districts (figure 1).

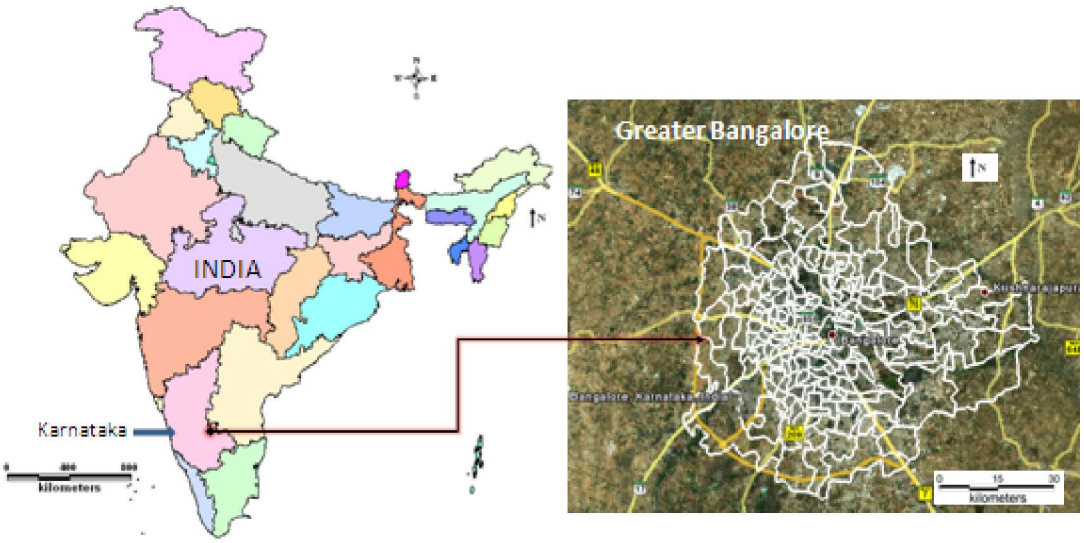


Figure 1: Study Area

## 3.0 Method

Stratified random survey of households was undertaken during Aug-Dec-2011 through a structured and pre-tested questionnaire in select wards of Greater Bangalore to elicit information related to household energy consumption for cooking, water heating, mobility, etc. Survey has been carried out in 1967 households covering different wards of Bangalore.

Questionnaire was designed to compile data covering various parameters such as satisfaction with overall environment, residential status, building type, kind of facilities near home and energy consumption behavior of households. Energy consumption in the household is the outcome of various household activities depending on the gadgets, efficiency of the gadgets, kind of fuel used, etc. Carbon emissions due to electricity consumption is computed by equation 1.

$$C = \beta E \qquad \ldots 1$$

Where $C$ is carbon dioxide emission β is emission factor (.81 ton/MWh) for carbon dioxide and $E$ is consumption of electricity.

## 4.0 Results and Discussion

Data compiled from 1967 households reveal that 50% satisfied with the overall environment of the Bangalore. Figure 2 illustrates the spread of 1967 samples across various wards of Bangalore. 226 households are very satisfied, while 1086 are satisfied with over all environment and about 162 households are very unsatisfied.

Figure 3 shows the residential status of sampled houses.1399 households are local urban residents. Northwest and Southwest regions are dominated by rural residents and about 11% are non-local residents followed by 10 foreigners.

Figure 4 depicts the distribution of type of houses and about 801 are single story row houses. It shows about 42% are low-rise apartments. Detached house or town houses are more in South East Area. High rise buildings are concentrated in the center of the city.

Figure 5 shows that 1549 households uses LPG for cooking and about 12% uses both LPG and electricity for cooking and 33 households use only

electricity for cooking. LPG is used almost in every house either with electricity or with fuel wood.

Figure 6 show that 782 households use electric heater for water heating (bathing purpose) and about 24% use solar water heater. Solar energy devices are being opted in Bangalore due to the government policy of provision of incentives for solar water heater users in the monthly electricity bill. Solar devices do not emit GHG's. Survey results reveal that 584 households have installed solar appliances due to the government's encouraging policy (Figure7). About 441 houses indicated of their plan to install solar appliances (Figure 8).

Figure 9 shows ward-wise $CO_2$ emission due to electricity consumption and the total emission is about 1940.629 Gg/year which is very high compare to other cities. Most wards emit between 5 to 10 Gg/year. Wards having emission more than 15 Gg is mainly located at the center of the city.

## 5.0 Conclusion

Emissions from household sector in Bangalore aggregates to 1940.629 Gg/yea based on the stratified random survey of 1969 households across various wards. About 24% of samples have opted solar appliances due to the incentives provided by the government.

## 6.0 Acknowledgement

We are grateful to Asia-Pacific Network (APN) for Climate Change Research (ARCP2010-15NMY-Han) and the Ministry of Environment and Forests, Government of India and Indian Institute of Science for the financial and infrastructure support.

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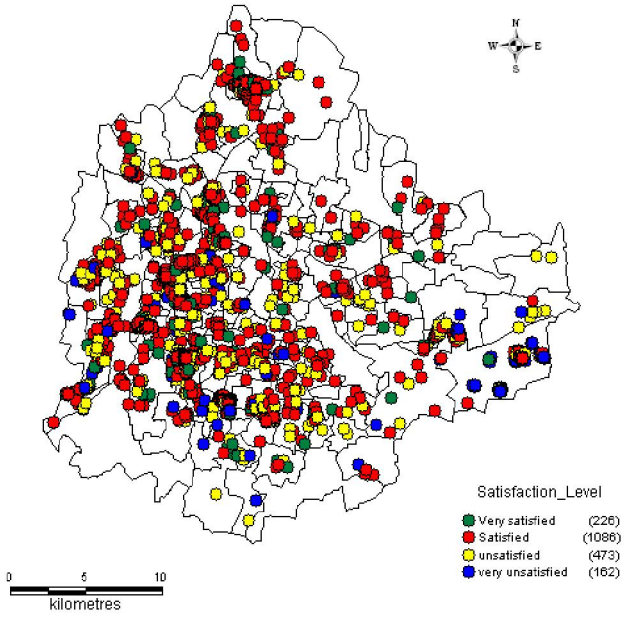


Figure 2: Satisfaction with overall environment

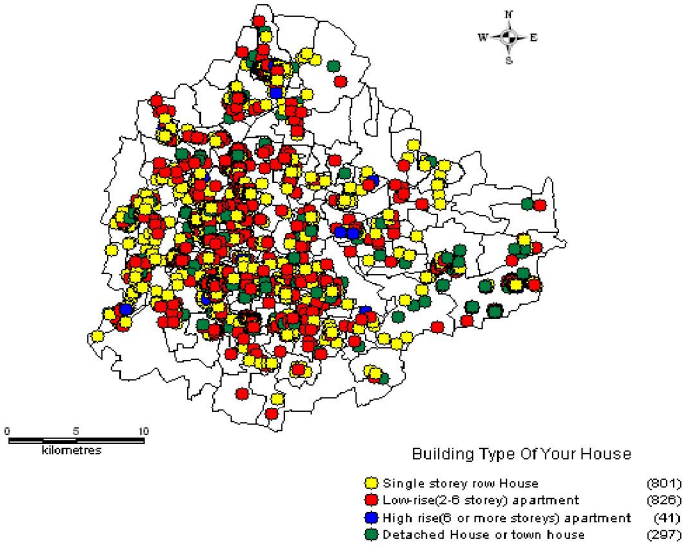


Figure 4: Building Type Of your House

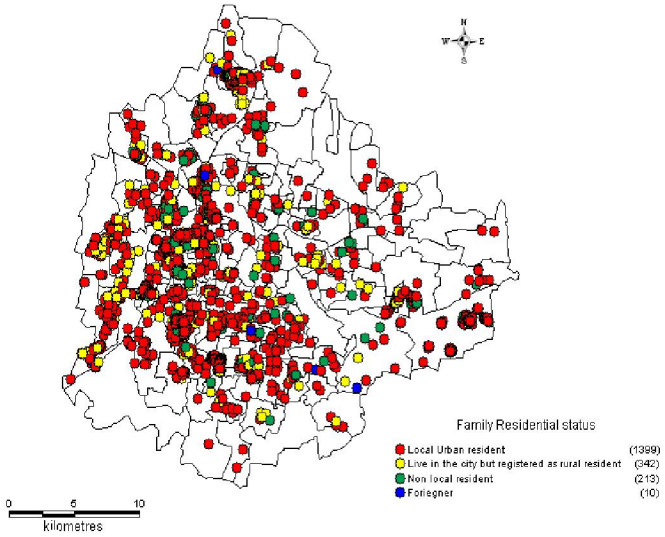


Figure 3: Family Residential Status

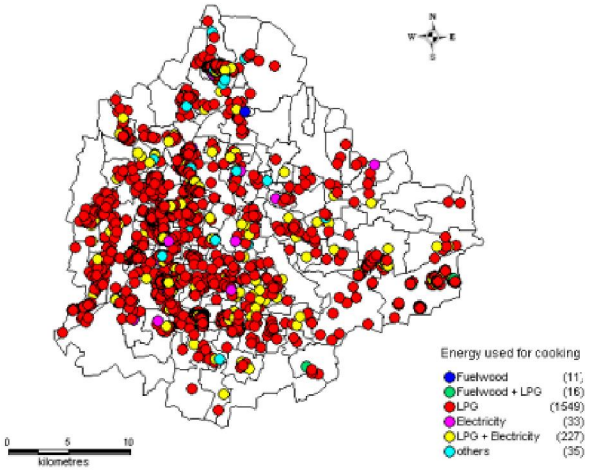


Figure 5: Energy used for cooking

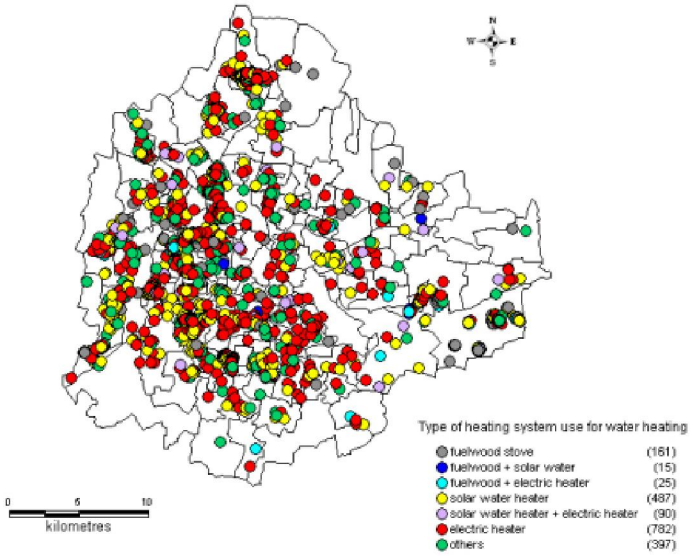


Figure 6: Heating system for water heating

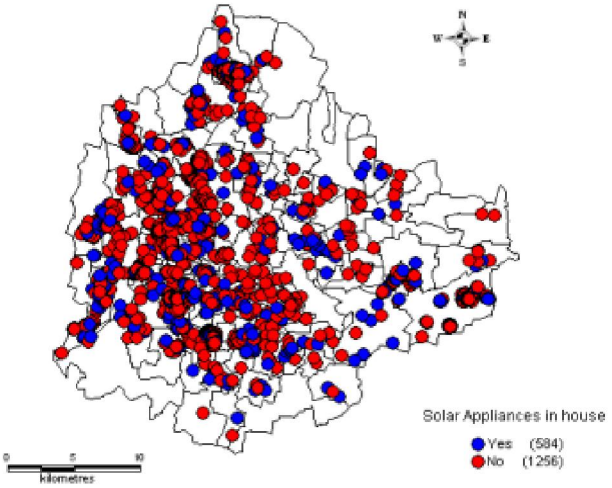


Figure 7: Solar appliances in house

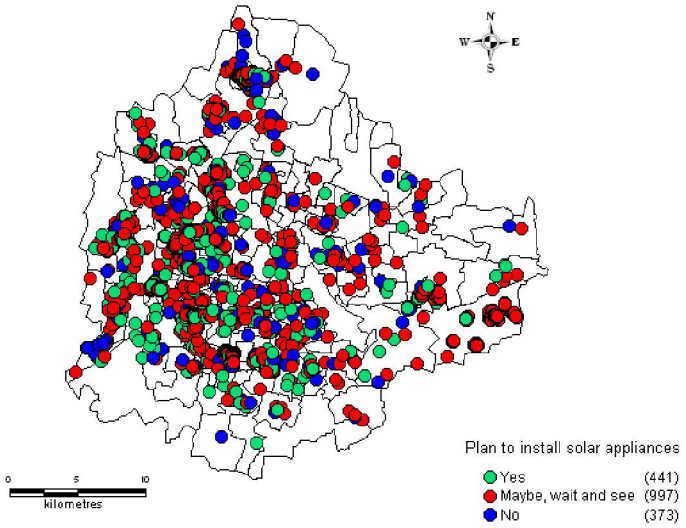


Figure 8: Plan to install solar appliances

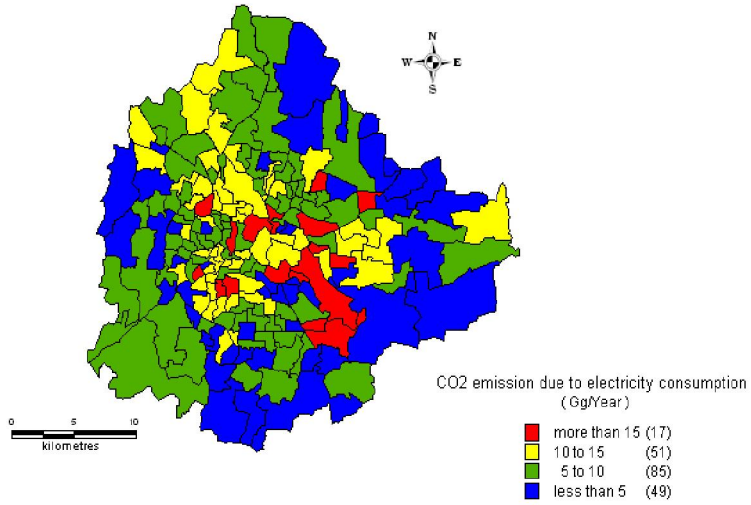


Figure 9: $CO_2$emission due to electricity consumption