Carbon dioxide land Footprint - A study of Ulli Panchayat village, Gudiyattam block, TamilNadu, India

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Abstract

This research uses Ecological Footprint as a tool to assess Carbon dioxide land Footprint of Ulli panchayat village situated in Gudiyattam block, Vellore district of Tamilnadu, India. An attempt was made to use "Bottom-up approach" to generate Carbon dioxide Land Footprint through direct measurement of direct energy and Embodied energy of consumption of Ulli Panchayat village. An assessment of national CO_2 land footprint was done to understand variations amongst energy sources and its contribution to emissions. Sub regional studies by using Bottom-up approach of this nature are crucial for spatial planners for future resource planning.

Keywords: Ecological Footprint, Energy consumption, CO_2.

1. Introduction

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs [1] (WCED, 1987). In this study, the sustainability is measured by comparing the ecological reserve (bio-capacity) and the energy consumption expressed as CO_2 land (Footprint). It would not be practically possible to compare between the bio-capacity and the Footprint unless both the parameters are converted to a common and comparable units. In this direction, a pioneering work was done by Prof.William Rees and Dr.Mathis Wackernagel to convert the resource and energy consumption and the biocapacity into standardized unit of area called "Global hectares"[2] (Scotland's footprint, 2004). In this paper an attempt is made to assess the CO_2 land footprint of Ulli Panchayat village using bottom-up approach.

1.1 Greenhouse gas

Amongst Greenhouse Gases (GG), global emission composition for the year 1995 Carbon monoxide (3.35%), Non-methane VOC emissions (0.63%), sulphur dioxide (0.56%) and nitrogen oxide (0.39%) with the exception of CO_2 (95.08%) for the year 1998,as shown in Fig 1 [3] (Earth Trends, 2003). India's emission composition of CO_2 (93.39%) for the year 1998 and 1995 as reference year for other gases, are Carbon monoxide (4.85%), Nonmethane VOC emissions (0.72%), sulphur dioxide (0.57%) and nitrogen oxide (0.47%) as shown in Fig 2. This shows that among, Carbon dioxide is the highest at both global (95.08%) and also at national (India) level (93.39%). It reveals that carbon dioxide emission reduction is the singular solution for $_{GG}$ problem. In this context, through biological process of photosynthesis sequestering of carbon dioxide is a promising option. Photosynthesis is a renewable and natural process of sequestering CO_2 by trees, which require productive land. A comparative assessment of CO_2 emission contribution by different energy sources at national, Asia and global level is shown in fig 3.

Fig.1. *Global emission composition-percentage wise*

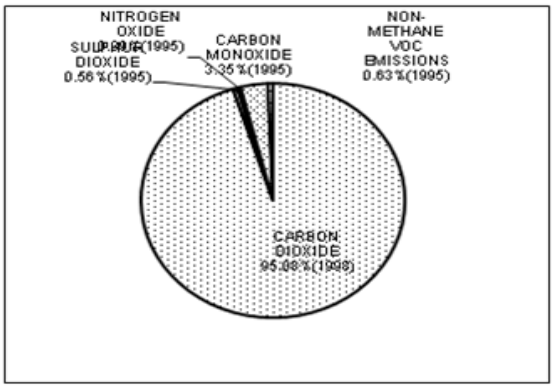


Fig.2. *India emission composition-percentage wise*

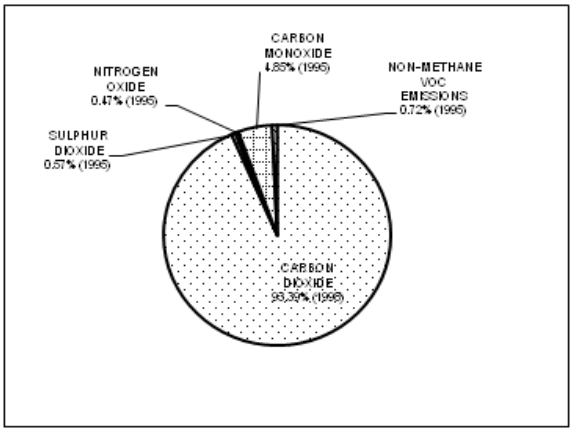
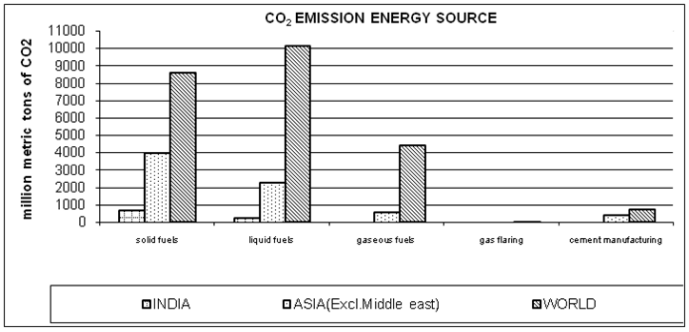


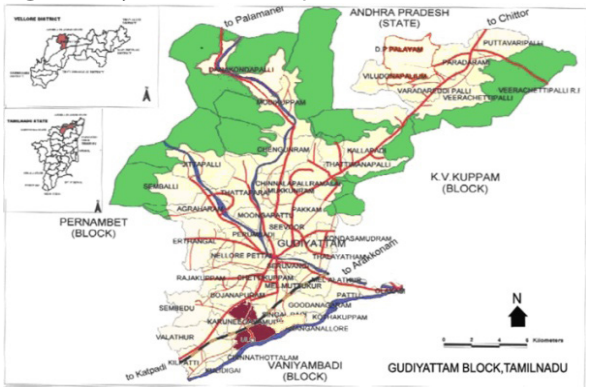
Fig.3. *Comparison of CO_2 emissions by energy sources-India, Asia (excl.middle east) and world.*



1.2 Introduction to the study area

Gudiyattam Block is located in the northern part of the district of Vellore. It lies between 12° 15' to 13° 15' North latitudes and 78° 20' to 79° 50' East longitudes in TamilNadu. It covers an area of 220.19 Sq.Km and with a total Population of this Block is 252338 as per 2001 Census. This Block consists of 53(44 panchayat) Census Villages. Ulli panchayat village is part of the gudiyattam block and has a population of 2486 (census, 2001) with land extent of 234.69 hectares as shown in Fig.4.

Fig.4. *Gudiyattam block map*



This block is primarily dependent on Agriculture. Some of the main crops raised in the block are Paddy, Ground nut, Coconut, Sugarcane, Banana, Choler and vegetables like Tomato, Brinjal, etc. Apart from agriculture; Weaving and Beedi work are other main occupation. There are 7 Weaver's societies in the block. Furthermore there are 3 spinning mills in Gudiyatham. Match work is functioning as cottage industry. Matches and Lungies produced in the block are exported to other states like West Bengal, Gujarat, and Maharashtra. Beside the above industries Beedi manufacturing is an important item of work in this block.[4] (Block statistical handbook, 2004-05)

2. Methodology Of Ecological Footprint Computation

Rees[5](1992) and Wackernagel[6] (1994) developed the Ecological Footprint as a synthetic indicator to estimate a population's impact on the environment due to its consumptions; it quantifies the total area of the terrestrial and aquatic ecosystems necessary to supply all resources utilized and to absorb all emissions produced.

2.1 Ecological footprint- carrying capacity

Ecological footprint analysis essentially inverts the logic of carrying capacity, defined as the maximum load exerted by the population of a certain species that a territory can support, without compromising its productivity. The ecological footprint focus is not to determine the maximum human population that an area can support, but to evaluate the productive territory actually used by residents, recognizing the fact that this ecosystem area does not coincide with the area where that same population lives.

2.2 Ecological footprint-landuse types

Wackernagel and Rees [7] (1996) proposed the ecological footprint calculation that is based on the average population consumption data that are translated into uses of productive land. The land is divided into 6 categories, following the classification of the World Conservation Union: (1) cropland; (2) grazing land; (3) forest; (4) fishing ground; (5) built-up land; (6) energy land. Each kind of land is characterized by a different productivity and this factor is taken into account to calculate the ecological footprint final value. In order to make the six different kinds of land comparable with each other, the classic formulation of the ecological footprint introduces a normalization process, in which the areas of different types of land are weighted by specific equivalence factors, based on the different bio-productivities. The measurement unit for these areas is the global hectare (gha).

2.3 Ecological footprint-Applications

Nowadays, the studies and analyses that utilize such indicators are extremely numerous and they regard very different geographical regions and spatial scales. Also, the scientific literature on this subject is quite extensive and rapidly expanding. A complete and systematic review is outside the scope of this article. We would like to mention here, along with the initial pioneering works[8,9,10,11,12,13] (Rees, 1992, 1995, 1996; Rees and Wackernagel, 1994, 1996; Wackernagel and Rees, 1996), the monographic issue of the journal Ecological Economics [14](2000), a critical examination of the limits and potentials of this indicator. Of great relevance are also the various editions of the Living Planet Report [15,16,17](WWF and UNEP-WCMC, 2000, 2002, 2004) that report the calculations for the world nations with populations higher than 1 million inhabitants, and that have contributed to the systematization and in-depth study of the calculation formalism. Furthermore the Final Report, written for the European Common Indicators Project EUROCITIES [18] (Lewan and Simmons, 2001) examines methods and criteria to apply the ecological footprint analysis to territories on a sub-national geographical scale, and provides 14 criteria and 5 recommendations, most of which have been strictly followed throughout the realization of the present calculations for the area of Ulli.

2.4 Ecological footprint: standards

In the year 2004, Wackernagel and collaborators founded the Global Footprint Network, a network of research institutions, scientists and users of this indicator that aims to further improve the calculation methods and bring them to higher standard levels therefore fostering its scientific robustness and its diffusion. Subsequently Footprint standards 2006[19](Footprint standards, 2006) were released, and this study of Ulli is in conformity with standard 3.2, 3.3 and guideline 3B of sub national calculations. [20] (Footprint standards, 2006). This study uses top-level consumption component categories such as Food, housing, transport and goods as per the standards.

2.5 Ecological footprint:" Bottom-up approach"

Primarily this study differs from Standard 3: sub national calculations, in which top-down approach as a method was suggested for computation footprint for sub national population. The " top-down approach" has a limitation of not capturing variations amongst regions and sub-regions, which is vital for regional planning and sustainability. So this study proposes an alternative methodology of "Bottom–up approach", by aggregating local level resource and energy consumption for assessment of regional sustainability.

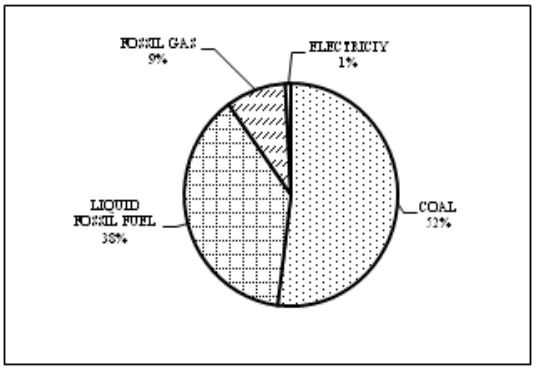
3. Calculation Methods And Data

This study used two methods for computation of CO_2 land footprints. First method is "top down approach" in that national level consumption of energy and associated emissions were computed and on per capita basis. Second method is "bottom up approach" by conducting primary survey of households in Ulli panchayat village and CO_2 land Footprint on per capita basis was computed.

3.1 Top down approach

At national level, types of by energy by source and their composition were identified. First, computation of energy sources and their total consumption by India in GJ (Giga Joule) was done. Amongst energy sources, composition of Coal (52%), Liquid fossil fuel (38%), Fossil gas (9%) and Electricity (1%) is as shown in fig 4. This reveals that coal is principle energy source.

Fig.5. *Energy consumption by source –India –percentage wise-2005-06*



Coal is the dominant commercial fuel in India, satisfying more than half of India's energy demand. Power generation accounts for about 70 percent of India's coal consumption, followed by heavy industry.[21](EIA, 2005). An analysis at National level power generation for the year 2005-2006 reveals that thermal power is the major component as shown in fig 5, indicating high emission and resulting in environmental degradation.

Further analysis at national level power generation and their energy sources would reveal level of dependency on fossil fuels. Among energy sources Thermal is the highest, nuclear and renewables are the lowest as shown in fig 5 indicating high emissions and unsustainability. From the above computation, CO_2 land footprint per capita was generated as shown in Fig 6.

Fig.6. *Power Generation-Electricity by source –India (in 000 Gj)-2005-06.*

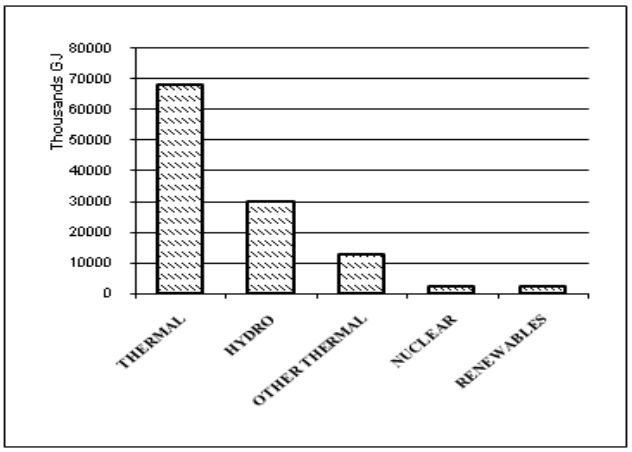
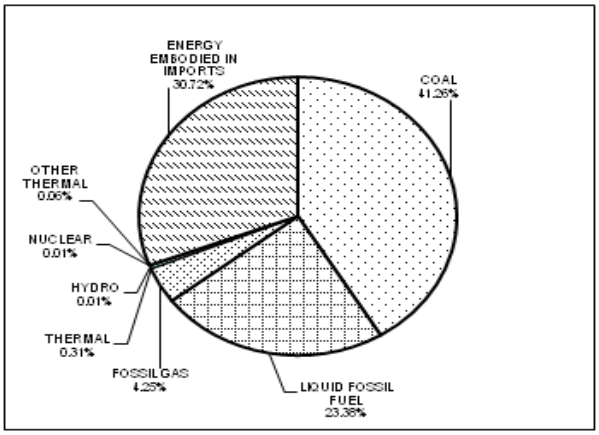


Fig.7. *CO_2 land footprint per capita- energy source wise-india-2005-06.*



3.2 Bottom –up approach

In this method, direct measurement of consumption through sample survey of households was conducted. The household level data regarding different types of energy consumption related to households (firewood, coconut shells, kerosene, LPG) was obtained.

At panchayat level, the data regarding different kinds of consumptions such as number of housing by building walling/roofing material (mud house, Thatch house, terrace house, Hut, tiled

house, IAY, others) was collected . Energy consumptions related to transportation (Petrol, diesel, fuel oil, LPG) was estimated partially from primary and secondary data.

3.3 Direct measurement of consumption

This study made a novel attempt by measuring consumption directly through random sampling survey of households in the study area. The size of the sample is limited to 3% of the number of households in the study area. The average household consumption of sample was obtained and extrapolated to generate total panchayat consumption. The sample questionnaire contained primary ecological footprint consumption component types such as i) food, ii) housing, iii) transportation, iv) goods. The sub-classification of primary level components was as shown in table 1.

Table 1. *Classification of Primary footprint consumption component types.*

S.No	Primary component	Ist level classification	Sector	II level classification
1	Food	Food	Household	Animal based
			Household	Dairy based
			Household	Cereals
			Household	Others
			Household	Pulses & spices
			Household	Oils
			Household	Fruits
			Household	Vegetables
			Household	Cotton consumption
		Marine food	Household	Fish, prawn
2	Housing	Building, Embodied energy	All sectors	Building material walling and roofing
		Timber	Household	Fire wood, paper
		Direct energy	Household	LPG cylinder, kerosene,
			All sectors	Electricity
3	Transportation	Embodied energy	Household	Transporting food & marine food, Transporting paper, for transporting Lpg cylinder, kerosene, for transporting diesel and petrol, transport.
		Direct energy	All sectors	Liquid fossil fuel consumption by Tractor, power tiller, sprayer, two-wheeler.
4	Goods	Embodied energy	Household & other sectors	Household products, aluminum products, Iron & steel products, Brass products, Plastic products, Electronic products, Electrical products, Stainless steel products, wood furniture, synthetic textiles, Telecom products, Tractor, power tiller, sprayer, two wheeler, four wheeler, bicycle.

Special attention was given to the calculation of the energy consumption ecological footprint that represents the CO_2 land Footprint.

Global energy consumption values for solid, liquid, gas combustibles, for electric energy (either thermal, hydroelectric, and obtained from other renewable sources) standardized by founders of Ecological Footprint were used in the computation of CO_2 land footprint.

Table 2. *Consumption category-data sources*

S.No	Data	Source	Year
1	**Food** consumption	Primary survey	2006-07
	Marine food consumption	Primary survey	2006-07
2	**Housing**		
	Type and no of houses	Panchayat development report, ananganallore	2004
	Fire wood, paper	Panchayat development report, ananganallore	2004
	Coconut shells & waste	Primary survey	2006-07
	LPG cylinder, kerosene	Panchayat development report, ananganallore	2004
	Electricity	Office of the Executive engineer, TNEB, vellore, & Panchayat development report, ananganallore	2004
3	**Transportation**		
	Embodied energy	Primary survey	2006-07
	Direct energy	Panchayat development report, ananganallore, Primary survey.	2004,2006-07
4	**Goods**		
	Embodied energy	Panchayat development report, ananganallore, Primary survey. & Primary survey,	2004, 2006-07

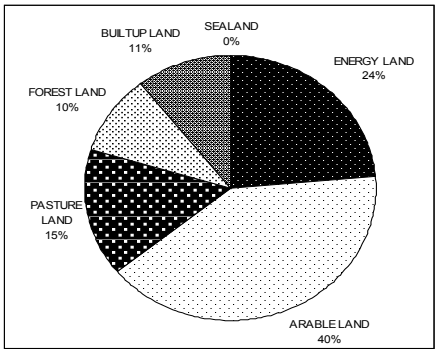
4. RESULTS

4.1 Disaggregated results analysis

4.1.1 Ecological footprint and ecologically productive land categories

Fig. 7 shows the ecological footprint of the Ulli panchayat village disaggregated according to the categories of ecologically productive land. It is evident among the Footprint, arable land (40%) is the highest, followed by Energy land (24%). The CO_2 land footprint is one fourth of the total footprint. In general, one may say that the Ulli panchayat follows a trend that is quite distinct from other industrialized areas, in which energy land footprint represents between one and two thirds of the entire value of the ecological footprint.

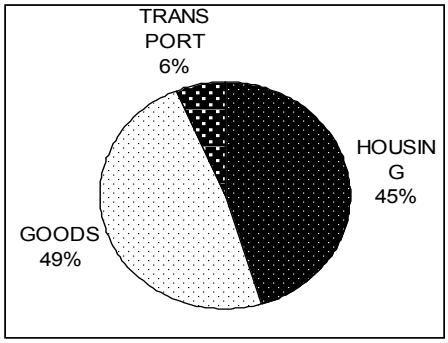
Fig.8. *Ecological footprint per capita(Ulli) –distribution by land use -percentage wise*



Within the energy land, both direct energy use and embodied energy use were computed. Direct energy use computation was done for Household electricity consumption, LPG and Kerosene, Liquid fossil Fuel consumption of vehicles (farm equipment) operating in the study area. Embodied energy computation for housing, transport, goods and embodied energy in transporting food, goods, paper and liquid fossil fuel was done.

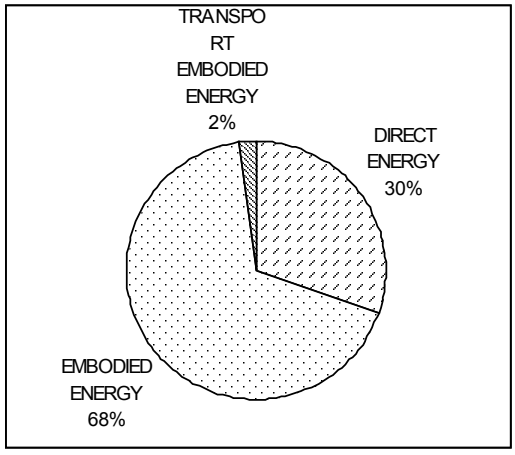
A further analysis of the categories that contribute maximum to the CO_2 land footprint was attempted, to understand the real causes of environmental impact and induce the undertaking of corrective actions. An analysis of CO_2 land Footprint sector wise is shown in Fig 8.The CO_2 land footprint distribution sector wise is goods (0.029 ha), housing (0.027 ha) and transport (0.0038 ha) per capita.

Fig.9. *CO2 land footprint per capita(Ulli)-Energy consumption –sector wise- percentage wise*



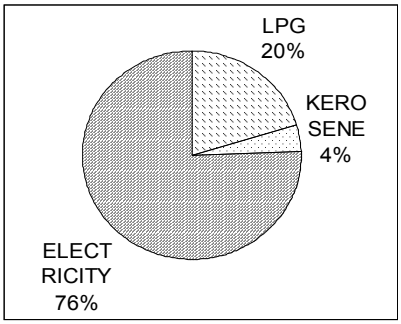
Housing sector(0.027 ha) is the second highest contribution to energy consumption. Further analyses in housing sector reveal the potential for reduction of CO2 land Footprint. The energy consumption distribution is Direct Energy consumption (30%), embodied energy consumption (68%) and less than 2% for transport embodied energy for imported commodities as shown in Fig.9.Embodied energy is inherent in materials and no reduction is possible in this component. Direct energy component is the second highest (30%) and has the potential for reduction.

Fig.10. *CO_2 land footprint per capita (Ulli)- Energy consumption -distribution-Embodied, Direct and Transport embodied energy.*



Amongst, direct energy consumption categories Total settlement electricity consumption footprint per capita amounts to (76%), Household energy- LPG (20%), Household energy-kerosene (4%) as shown in Fig 10.This analysis is useful to conclude that decentralized power generation substitution of electricity through renewable sources has the potential to reduce the CO_2 land Footprint.

Fig.11. *CO_2* land footprint per capita (Ulli)-Direct energy consumption -source wise



It is possible to analyze in detail CO_2 emission component of electricity, by highlighting how energy sources sector wise are contributing to the CO_2 emissions such as domestic (30%), agriculture (44%), streetlights (26%), as shown in Fig 11.An analysis of Electricity energy consumption by sector wise at national level as shown in Fig 12 was computed to reveal variation among different sectors.

Fig.12. *CO_2 land footprint per capita(Ulli) –direct energy consumption –electricity – sector wise*

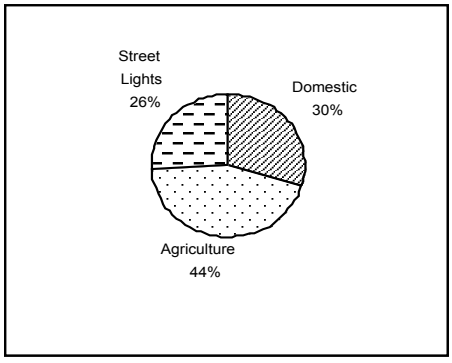
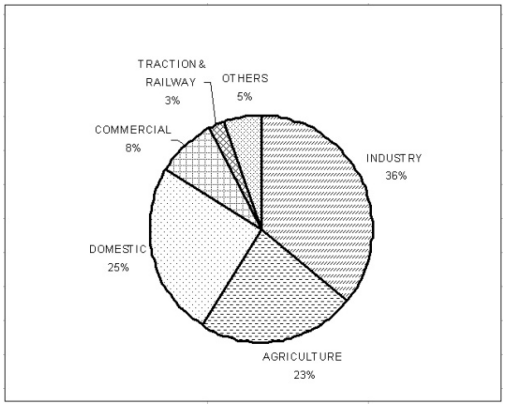


Fig.13. Energy consumption –Direct energy consumption (Gj) –electricity (India) – sector wise



5. Conclusions

This paper presented the results of the analysis of the CO_2 land footprint of Ulli panchayat village and national CO_2 land footprint. This study attempted to compute CO_2 land footprint by both approaches namely, Bottom-up and top-down. The calculations were performed in such a way as to ensure a high range of

possible disaggregations of the final results, according to categories of productive land and consumption.

The bottom-up approach methodology, that was used in this study, is unique and through exhaustive and extensive primary surveys and local data collection, adapted panchayat village level data and assessed CO_2 land footprint. The computations used 80 % of the data from primary field surveys, 15% from secondary sources and 5% proxied (Electricity) from national/state level data.

This study validated the "Bottom up approach" methodology to assess panchayat village level CO_2 land footprint. This study has resulted in detailed data on consumption of renewable resources and non-renewable resources in the study area. Through this study it was possible to delineate a coherent and exhaustive quantitative picture of the complex relationships between society and environment in the Ulli Panchayat village. Replication of similar studies in other panchayat villages across Gudiyattam block provide the public administrations and decision makers with an overall perspective on the problem of energy consumption, associated emissions and the potential for reduction of emissions.

6. Acknowledgements

This Research project was sponsored by Department of Science & Technology, Government of India and carried out at Department of Planning,Anna University,Chennai.

7. References

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