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STUDY ON GREENHOUSE EMISSION FROM FOOD WASTE- AN LCA APPROACH

P. Krithiga* & G. Senthilkumar**
Department of Civil Engineering, Faculty of Engineering and Technology, Annamalai University, Annamalai Nagar, Tamilnadu

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Abstract:

The term carbon footprint becomes extremely popular and now increasingly being used across the media, government, researchers and by the business world. Carbon foot print is the way of estimating the Greenhouse emission (GHE) caused by an event, organization, and product or by a person. Products of the carbon foot print are measured by undertaking a greenhouse gas (GHG) emission assessment. Over the years the emission of greenhouse gases and the environmental implications specifically the global warming has been studied extensively. The sectors like industries, transportation, energy generation, food production and waste management are identified as major contributors of GHG emission. Presently due to growing population and changes in life style, management of food waste has become an issue in all the major economies of the world. The effect of wasted food products on the environment throws major challenge to waste managers. International organizations on food waste management supports the concept of Life Cycle Approach (LCA), as it is very useful to assess the environmental impact caused by the food waste, since it takes into account the all possible impact including the greenhouse emissions. The life cycle of food product causes several emissions in the platforms like production, transport, processing and preparation, before it is being wasted. Also the CO_2 emission arises by the use of fossil fuel, while the CH_4 is due to the enteric fermentation in ruminants and rice fields, application of nitrous oxide to the soil through fertilizer. In the present study an attempt has been made to estimate the greenhouse emission (GHE) of an institutional area arising out of the food waste from hostels. Field level monitoring and measurements were made continuously 15 days for the assessment of food waste from hostels and questionnaire survey has been carried out with all stake holders to identify and to understand the existing status of purchase of material, transport, processing and its use. A Bottom up approach has been adopted for the present study to analyze the carbon foot print of wasted food products. The data from field level study and results of the questionnaire survey were given as input to the Food carbon Scope ™ (Clean metrics, USA, 2011) a software tool used specifically for the assessment of carbon foot print emerging from food and beverage products. The carbon dioxide equivalents were also estimated and inferences were made based on the results.

Key Words: Carbon Foot Print, Green House Emission, Global Warming, Life Cycle Assessment & Food Carbon Scope

Introduction:

The economic status of the developed nations has reached to an extent that thousands of tons of wholesome edible food are thrown away as waste at every stage of the marketing system. Food waste has been studied for many years, its significance and its effects on environment are well known. As one-third of the world's food is estimated to be wasted (FAO,2013), food waste has been identified as a major problem in terms of disposal and needs to be solved so as to achieve sustainable development. A report of the CSR Journal states that food waste generated in India equals to what the United Kingdom consumes. Food is one of the important resources and offers energy. Presently food waste in India is increasing day by day and originates from marriage halls, canteens, hotels, social and family functions and household discharges. Previous researchers reported that in India the food wastage is about 25% of the nationally available food. Management of waste specifically segregation of waste at source, use of small scale bio digester and composting at source are the measures suggested to reduce carbon foot print (Tina Schmiefer., 2012). Wastage of food occurs at all stages of the life cycle of food starting from harvesting through processing and production by way of transportation and finally consumption. Fifty-four percent of the world's food wastage occurs "upstream", during the production, post-harvest handling and storage and the remaining forty-six percent of it happens "downstream" during the processing, distribution and consumption (Pathak, et.al., 2010).Food loss and the food waste leads to the major resource depletion including land, energy and generally produces greenhouse gas emission which leads to the climate change and global warming. The greenhouse emission (GHE) arises from the global food consumption can be studied by a twin approach like Pre-consumer and Post consumer. The growing interest in the food waste management in recent years has been the important topic of both natural and environmental studies. Research into the environmental effects of the food consumption usually focuses on the energy and the production of the waste (Pathak et al 2010). The prevention of wasting food could be the important contribution to saving not only the resources but also reduce the environmental impact during the production, transport and waste management of the food system.

The concepts of carbon footprint were introduced a decade ago. The 'carbon footprint' has become popular over the past few years and is now widely accepted and used by the public and media despite its lack of scientifically accepted and universally adopted guidelines. The origin of carbon foot print is traced back to a subject as ecological foot print proposed by Wackernagel and Rees., (1996), accordingly the carbon foot print refers to the land area required to assimilate the entire CO_2 produced by the mankind during its lifetime. It describes greenhouse gas emission measurement from the narrowest to the widest sense. Several calculation methods and approaches for carbon footprint accounting have been proposed and are being used. Similarly it is expressed that 'carbon footprint' is a measure of the greenhouse gas emissions associated with an activity, group of activities or a product. The scope of the Carbon footprint can be from two forms direct and indirect emission. Thomas Weidmann, et.al (2008), addressed the definition and the methodological implication of the carbon footprint. The term carbon footprint is commonly used to describe the total amount of CO_2 and other greenhouse gas (GHG) emissions for which an individual or organization is responsible. Footprints can also be calculated for events or products. The main reason for calculating the carbon footprint is to manage the footprint and to reduce the emission over time. The Intergovernmental panel on the climate change (IPCC) in its fourth limits strongly recommended for limiting the increase in the global temperature below 2°C compared to the pre-industrialized level and stressed the importance of estimating the carbon footprint (Divya Pande, et.al., 2011). Among the several methods available to measure the carbon footprint, the most reliable approaches include bottom-up, top-down and hybrid approach using the technique of Life Cycle Assessment (LCA). The LCA methodology was designed to assess the environmental impacts associated with products, processes or activities. LCA is applied to the life cycle of food, and each of the following life stages of a product is analyzed: origin, agricultural growing, production, food processing, packaging and distribution, preparation and consumption and the end of life. The life cycle assessment of food and the environmental impact of the food show the emission of greenhouse gases specifically carbon dioxide, methane and nitrous oxide (Satpute, et.al 2013 and Pathak, et.al ., 2010).

Among the various carbon footprint calculators used to estimate the individual carbon footprint the United States based calculators reveal carbon dioxide emission per annum associated with the individual profile (J.Paul Padget, et.al 2007). The scope of the user behavior, data source, and transparency of the method and effectiveness of communication has its influence in carbon foot print (Brent Kim, et.al, 2009). Similarly carbon foot print calculators are being used in food sector, specifically to estimate the carbon foot print arising out of production, transportation, processing, cooking and consumption (Pegahamani, et.al. 2011). The wasted food items can adversely cause impacts on land, water, biodiversity and may lead to environmental degradation. The food waste has a strong impact on the global climate change and on the economy (Kumar Venkat., 2011). If the food waste is thrown away in the landfill it will degrade anaerobically and emit methane (CH_4) gas. Even though food and agricultural systems heavily depend on the fossil fuels, the petroleum products are used in almost every aspects of food production from fertilizers, mechanized planting and harvesting, irrigation, cooling and transportation. With this back ground an attempt has been made to study the carbon footprint of the wasted food in an institutional area in terms of the greenhouse gas. Bottom- up approach has been used for the present study. Food such as cabbage, okra, eggplant, potato, cauliflower, carrot, beans, beets, plantain stem, tomato, onion, spinach, pumpkin, radish, rice, milk, flour, grains, chicken, fish and vegetables of the waste food item were analyzed.

Study Area:

The Study area, Annamalai University is located in Annamalai Nagar, Cuddalore District, Tamil Nadu state which is in the plains of Southern Peninsula. The Annamalai Nagar region is designated by Department of Local Administration, Government of Tamilnadu special village panchayat and is immediately adjacent to the important temple town Chidambaram. The total geographic area of the Annamalai University is about 999 acres and the mean sea level (MSL) is + 5.74 with the Latitude and Longitude of 11°24' and 79°44' respectively.

Characteristics of Hostels:

Annamalai University offers a wide variety of courses and being a residential university it houses nearly 16 hostels for both male and female students, coming from the different parts of the country. Among sixteen residential hostels, five hostels were exclusively being used by women students (Thamaraiillam, Rose hostel, Agri Women's Hostel, W.H.P Hostel, T.S.A.N.S Hostel) and the remaining eleven accommodates Male Students (Malligaiillam Thendralillam, Mullaiillam, Travancore Hostel, RSA Hostel, Pothigai Hostel, E&T G.J Hostel, E&T D.J Hostel, K.R.M Hostel, PG Doctors, Kurinji Hostel). Almost nine thousand students are staying in these residences. The shopping Centres, temples, several nationalised and private sector banks are functioning within the campus. Mess and Canteen facilities are available in all these hostels. As students staying in the hostels are a diversified group the food habits and food preferences of the students vary widely. Presently there are 18 and 12 messes are functioning for the Men and the Women students which offers both vegetarian and the non-vegetarian foods. South Indian, North

Indian and Chinese's food items are being served for the students.

Materials and Methods:

The present study has been carried out in the institutional area during October 2015 for three weeks. In order to calculate the carbon footprint associated with the food waste, the food waste carbon footprint was calculated for different food products originating from hostel. In this study, the data food product like fruits, vegetables, meat, chicken and dairy products were analyzed. Existing literatures show that different methodologies are being used to calculate the carbon foot print. KatharimaScholz, (2013), defined the carbon footprint of food waste is the emission associated with the food production and transport which is multiplied by the wasted mass. The mathematical formulation used for estimating the carbon foot print of food waste is shown in Figure 1.

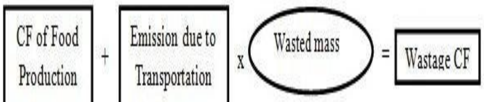

Figure 1: Carbon Footprint of Food Waste

Data Collection:

Both primary data and secondary data's are collected for the present study. Field level observations and measurements are made for primary data and the questionnaire survey, interviews with all stake holders are carried out. The first part of this study was started with the questionnaire survey and interviews. The data collection process took place in October 2015 and extended for three weeks. The survey has been taken in 12 hostels. The findings of five hotels have been analyzed for the present study. In this study, data was collected by field level observation. Out of 12 hostels, five hostels have been selected based on the strength of students; type of food served, preparing and transport distance of the food. After retrieving the data, sorting process was carried out for the individual hostels. The wastage of the food is measured per session and weighed by portable electronic scale. Daily consumption of the vegetables and scrapping pieces are weighted regularly. The food production is calculated by weighing the food products which is brought from the market. Transport distance is calculated as per the semi structured interview. Consumption of the food item is calculated by subtracting the scrapping pieces of the waste food.

Questionnaire Survey:

The questionnaire has been developed to determine the role of various attributes like purchase, transfer and transport, processing and cooking, consumption and wastage of the food in hostels. The design of the questionnaire includes a three response levels. The first part includes the particulars of the individual hostel. The second part contains characteristics of the hostels like nature of the food served in the hostel, no of chefs, strength of the students; timing for the cooking to prepare food, time to take food, percentage of the students taking the food during the week days and for the week end days were collected for individual hostels, wastage of the food per section, amount of vegetables consumed per day, energy consumption and equipment's used are also collected. The third part contains food related environmental issues like type of waste generating from the hostel, problems due to food waste disposal.

LCA Software:

Food carbon Scope ™ is the web-based software tool introduced by Cleanmetrics, USA for the modeling and analysis of all life cycle stages. It offers a cradle to grave approach for agriculture, packing, distribution, retail, cooking, waste disposal, water use, energy use and accounts for all the greenhouse gas emission in food and beverage products. Food carbon Scope ™ can be used in a different application like carbon and water footprint labels, environmental benchmarking for food and beverage food supply chain and some comparative evaluation for the alternate supplier. Using Food carbon scope, supply chain in the agricultural and water use can be modeled comprehensively which includes inputs like fertilizers, pesticides, irrigation, electricity, fuel use and transport emission. Food carbon Scope ™ takes into account the life cycle inventory database containing the cradle to grave unit process in food and in the agricultural sector which covers the wide range in the field of the production system, commercial food processing, packing and waste disposal. The majority of the data product includes US, Canadian, Asian Countries and some other parts of the world. Food Carbon Scope ™ generates the result with the international standards (ISO 14040 series, PAS 2050 Publicly Available Specification, Greenhouse gas protocol) for the life cycle assessment. Greenhouse Gas emission from agricultural soil, manure management, enteric fermentation and waste disposal are calculated by using the IPCC guidelines for the National Greenhouse Gas inventories. The working framework of the food carbon Scope in the life cycle stages is categorized into six bases like production, processing, distribution, retail, cooking and consumption. The production model includes complete cover-up and calculation in the agricultural production with the detailed inventory of the agricultural inputs and can be examined along with the soil condition, tillage/ management practices and change in land use. The processing model includes food processing methods, commercial cooking appliances and refrigeration, packing, fuel use and transport. The purpose of the processing includes the additional resource consumption and some emission generating step beyond the production model until the product enters into the distribution network. The distribution and retail model includes some storage facilities and some transport links. The cooking model used to generate the resource use and emission occurs during the preparation of the food. The consumption model can comprise the refrigeration, waste disposal and use of energy and water. Once the food product input is given in the life cycle stage, then the "Analysis" button generates the Life Cycle Assessment result. Food carbon Scope™ produces the result of the analysis in multiple forms. The results of the life cycle stage show the quality of the material at the output of each stage along with the primary energy. Greenhouse emission generated from waste usage and the emission contributed from the transport, packing and waste disposal can also obtained.

LCA Goal and Scope:

The goal of the LCA is to examine the birth of food waste starting from production till it reaches down as a waste, in an institutional area. The functional unit considered in this paper is one kilogram of food products. The spatial boundary for the LCA includes the cradle to grave starting from the extraction of raw material and ends with the disposal of the food product. The system boundary includes production, processing, transport, cooking, and consumption process. Food productions are considered to be occurring within the India. In the present study, it is assumed that the waste generation occurs during distribution and disposal of food. Also the food wastes have been treated as being disposed on to the landfill. The assessment period of the LCA is 20 years, i.e., the one-year food waste is calculated over the 20 year time horizon.

Estimation of Food Waste:

Five hostels have been selected based on the total strength of the student, type of food being served and transport distance of the food. The food production is calculated by weighing the food product brought from the market. Transport distance between the hostels and the market are calculated using Google Map. Estimation of total consumption of the food item are made by measuring the scrapping pieces of the wasted food item and total food waste are weighed after breakfast in the morning, after the lunch in the afternoon and after the dinner on daily basis using electronic scale. Table 1 show the various food items produced transported and consumed in all the ten hostels per day. The wasted mass is also calculated.

Table 1: Production, Transport and Consumption of Food Items

Food Category	Production	Transport	Consumption	Wasted mass
Cabbage	433.00	22.20	319.11	113.89
Okra	135.00	22.20	113.61	21.39
Eggplant	111.50	22.20	88.46	23.04
Potato	7.00	22.20	432.04	52.46
Cauliflower	104.50	22.20	6.30	12.56
Carrot	88.00	22.20	52.65	18.11
Beans	311.00	22.20	257.85	16.55
Beetroot	213.00	22.20	153.33	53.15
Banana	242.56	22.20	194.68	61.24
Tomato	244.56	22.20	200.15	22.08
Onion	150.00	22.20	106.66	35.85
Spinach	60.63	22.20	48.75	43.54
Pumpkin	56.00	22.20	46.35	12.47
Radish	215.00	22.20	195.57	10.41
Rice	190.00	22.20	175.72	20.19
Milk	143.00	22.20	80.70	16.56
Flour	26.00	22.20	22.30	23.32
Grains	60.00	22.20	48.90	1.06
Mango	70.00	22.20	55.65	12.36
Orange	45.00	22.20	38.45	16.36
Apple	10.00	22.20	7.49	9.23
Pineapple	10.00	22.20	8.56	2.65
Watermelon	15.00	22.20	10.00	5.89
Fish	10.00	22.20	10.00	1.36
Chicken	88.00	22.20	15.00	2.20
Mutton	30.00	22.20	10.00	0.25

All the values are in kg, Transport in km. Also for the measurement of carbon foot print it is assumed that majority of food consumed is produced in India and all the meat products being used are boneless equivalent. The climate zone has been selected as tropical – dry as defined by the IPCC, 2006. Based on the field level studies it is observed that semi-trailer trucks are being used for the transport of food commodities within the campus and the distance of travel by trucks ranges between 2 – 5 km. The field level studies show that food waste is co-disposed along with trash and refuse and open dumped on the land environment. Based on food product the moisture condition has been assumed as dry / moist / and wet and the cooking hour is has been considered as minimum one hour and it is depends on the nature of item being cooked.

Results and Discussion:

Waste Disposal Carbon Footprint Emission: The aim of the study to determine the Carbon footprint of food waste in the Annamalai University hostel in order to know the climate change impact and to identify the hotspot area and decision to reduce the efficiently. Table 2 show the carbon footprint of the food products which is calculated for the institutional hostels. The emission associated with the waste disposal carbon footprint has been calculated for the five hostels. All the emission is in terms of Carbon dioxide equivalents (CO_2- e) in Kg.

Table 2: Wastage Carbon footprint in Food Products

Vegetables	Vaigai Hostel	Rose Hostel	Travance Hostel	RMH Hostel	RSA Hostel	Waste Disposal Carbon Emission
Cabbage	0.566	4.540	0.570	--	1.250	1.731
Okra	0.476	0.645	1.900	--	0.242	0.815
Eggplant	0.118	1.004	0.164	0.183	0.090	0.311
Potato	0.527	8.517	0.960	1.353	0.810	2.433
Cauliflower	0.250	1.250	--	--	1.343	0.947
Carrot	0.000	0.295	0.065	0.315	0.139	0.162
Beans	0.160	1.107	0.085	0.735	0.325	0.482
Beetroot	0.521	2.560	0.460	1.319	0.700	1.112
PlantainSte	--	1.980	--	--	--	1.980
Tomato	0.128	5.313	0.917	2.865	1.770	2.198
Onion	0.185	0.634	0.230	1.127	0.390	0.513
Spinach	0.459	1.390	--	3.805	--	1.884
Pumpkin	0.172	1.200	0.106	0.550	0.357	0.477
Radish	0.576	2.230	0.172	1.010	4.490	1.695
Rice	9.767	45.750	4.460	10.144	9.600	15.944
Milk	7.505	26.540	15.300	6.930	23.16	15.887
Flour	1.510	5.690	3.590	--	--	3.596
Grains	0.305	0.202	0.140	0.890	0.220	0.351
Vegetables	2.950	1.493	--	--	--	2.221
Fish	--	6.390	--	--	--	6.390
Chicken	2.876	24.820	7.155	4.560	3.218	8.525
Mutton	2.958	23.89	5.156	--	--	5.23

The Figure 2 shows the wastage Carbon Footprint of various hostels. It is observed that the emission from rose hostel show a higher wastage carbon footprint. This is mainly due to increased strength of the students and higher food waste arising from the hostel.

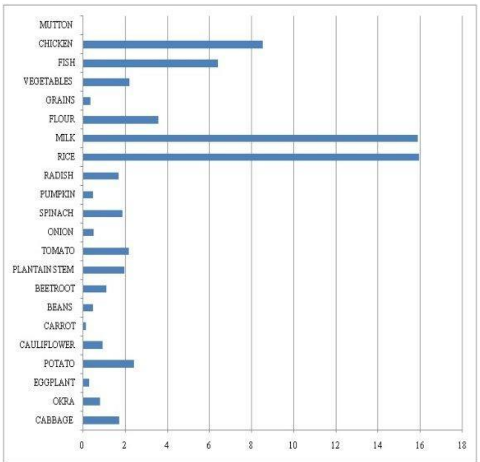

Figure 2: Wastage Carbon Footprint of Individual

Food Products: Figure 2, shows that the wastage of carbon footprint of various food products. From the figure 2 it is observed that rice (23%) and dairy (23%) products are contributing to higher carbon footprint. It is mainly because of intensive production process and higher consumption. The rice and milk product is followed by Chicken (12%) and Fish (9%). The overall Carbon footprint wastage of the fruits shows 3% due to the influence of the season and lower consumption. The other vegetables like potato (3%), cabbage (2%), okra (1%), cauliflower (1%), beans (1%), tomato (3%), and pumpkin (1%), and radish (2%), onion (1%).

Food Waste Emission per Day: Figure 4 shows the emission associated with food waste per day. The average greenhouse emission per day is 0.135 kgCO_2e. The transport emission which contributes 0.0107 kgCO_2e. The waste disposal emission per day shares 0.180 kg CO_2e.

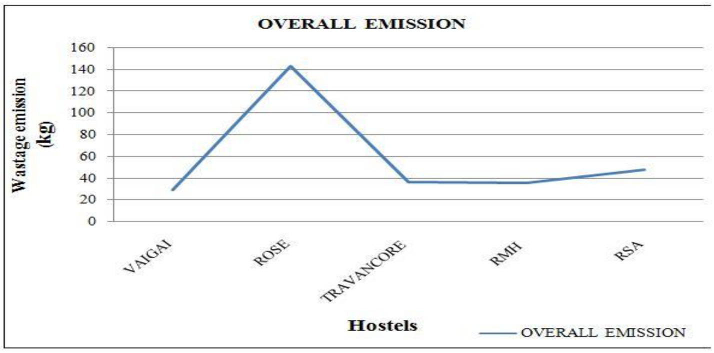

Figure 3: Wastage Carbon footprint of various hostels

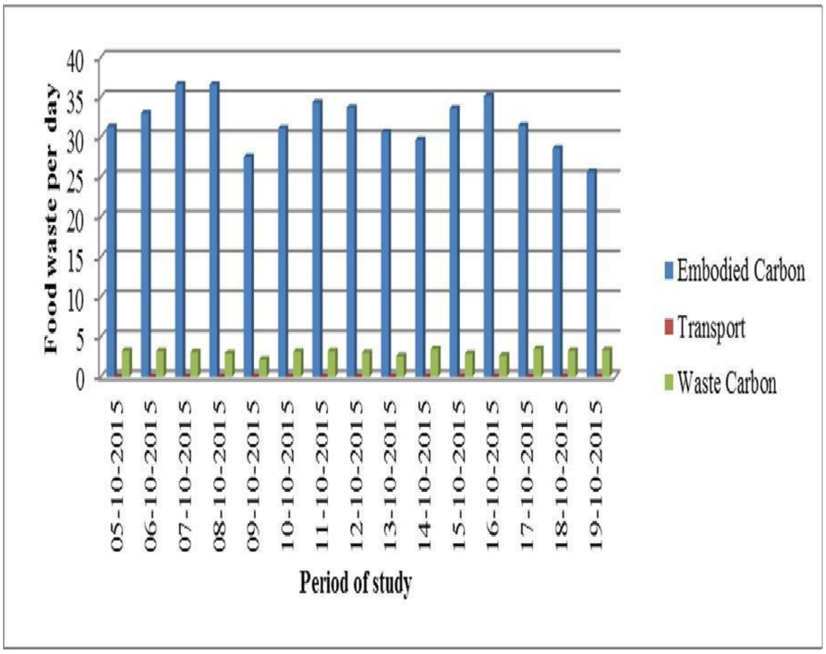

Figure 4: GHGs Emission Per Day

Life Cycle Emission Stage: The result shows that a total of 69.597 kg Co_2-e of waste is emitted. The average greenhouse emission per kg of food waste is 3.163kg Co_2-e. This includes the emission caused in the waste disposal for waste products analyzed in the present study. Katharina Scholz, (2013), estimated environmental impact on the food waste in the retail storage and reported as 1.61 kg Co_2-e

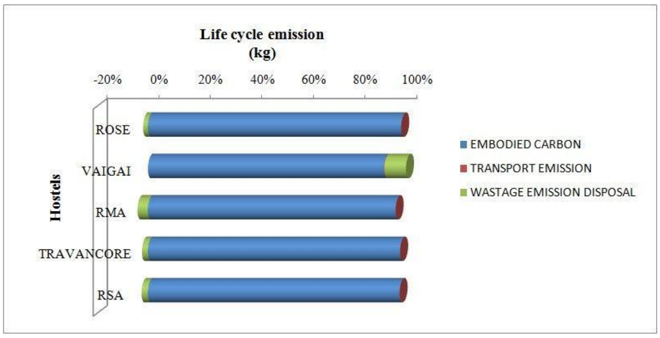

Figure 5: Emission Stage Carbon footprint for individual hostels

The figure 5 shows the life cycle emission stage carbon footprint for the various hostels. A trend similar to waste carbon foot print has been observed from the figure. A reduced carbon foot print has been observed for RSA hostel followed by Travancore, vaigai and RMH hostels. The RSA Hostel had the minimum student strength when compared to the vaigai hostel which shows the less consumption of food products. In total the transport emission for vaigai hostel (35%) contributes more when compared to other hostels. Rose hostel reaches (33%) of transport emission followed by the RMH (9%), Travancore (8%) and RSA (15%). The travelling distance considered in this study ranges from 2-5Km. In waste disposal the Rose Hostel contributes (-27%) more when compared to other hostels. The RSA hostel manages (-15%) follows by

Travancore hostel (-10%), RMH (-14%) and vaigai hostel (85%). This shows that the carbon footprint of food waste lead to the negative value except vaigai hostel. Both positive and negative emission values have been observed in the result. This shows that the certain amount of negative GHG emission means that the process is saving that amount of emission and it refers to positive environmental impact. On the other hand a process with a positive amount of GHG emission means the process is emitting the amount and it refers to the negative environmental impact.

Conclusion:

Based on the study it is observed that one of the biggest challenges in the Annamalai University is in ensuring the practice of source segregation across the campus. LCA has been one of the most important aspects in the food product but it receives messily concern and not comprehensively studied in India. As we are committed to reduce our Global warming to less than 2°C in the UNFCC (2015), there is the scope for implementing the Life Cycle Assessment. The present micro level study reveals that the food waste emission in the University Campus is standard, and we can reduce the carbon foot print by following ways: to eat optimal amounts of food; less food wastage; to eat local or seasonal or organic food. Also an appreciable quantitative reduction in purchase, source segregation of waste, optimizing the transport and processing involved in the food cycle may reduce the GHG emission. For achieving sustainable carbon footprint reduction student and staff outlook plays a vital role. The analysis of food waste carbon foot print presented here can further extended to areas like energy usage, refrigeration, climate change, water footprint, land use and other resources can be further added to the modeling and analysis of the results.

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