Carbon Footprint Calculation from Cradle to Grave: A Case Study of Rubber Manufacturing Process in Sri Lanka

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Abstract

The core objective of this research is to identify the carbon footprint of rubber based products in relevance to different phases of the manufacturing process to identify greenhouse gas emission effect correlated at different stages to establish mitigation strategies. In order to carry out research objectives; ten unstructured interviews were conducted with the relevant professionals to identify the propelling and the restraining forces to product carbon footprint. The Case study revealed that the product carbon footprint for non-organic scope was calculated as 6.67 kg CO2e per kg of latex foam produced an organic scope of 3.34 kg CO2e per kg respectively. It is clear that application of fertilizers during the cultivation would double the emissions in the final product. It further revealed that carbon emission in one kg of latex foam contribute to global warming of 47 percent due to cultivation, 45 percent due to foam production and 8 percent due to centrifuging.

Keywords: carbon footprint, emission, greenhouse gas, rubber, mitigation strategies, organic, non-organic

1. *Introduction*

As a course of concern apropos survival of mankind in our planet on the product carbon footprint (PCF) and Life cycle assessment (LCA) is proliferating worldwide through society as a topmost priority concerned in long term survival. The impression that is appertains to carbon footprint (CFP) offer and clues about where we have approached from and where we are heading in the course of an organisation's activities. It is interesting to analyze that organizational environmental behavior needs an aim within the current economic system. The manufacturing processers are concerned on sustainable development more than ever before and it that appears to aware of people, planet, and profits. Environmental factors concerning the organization focus more attention on natural resources to keep a balance between corporate bio diversity and process performances. A development necessarily means and that these are social, environmental and economic aspects in the three different perspectives in the organization. No expressive development destroys nature. The World Bank is speaking of going beyond Gross Domestic Product (GDP) and in fact what it has clearly cleared is not effective and is not tell the whole truth. We all know GDP does not capture social costs as well as environmental cost. In the current business scenario while businesses aim at result and in a healthy environment growth this is a necessary optimization of the available resources through an integrated development plan. The ultimate objective of such a plan is to provide of right or propitious opportunities for the environmental wellbeing.

How much greenhouse gases are associated with a product along its entire life cycle? This question has increasingly become more and more important over the past few years. PCF can help manufacturers to decide which products, processes and organizational innovations they should focus on to reduce greenhouse gas emissions during the supply chain. A carbon footprint measures the total greenhouse gas emissions caused directly and indirectly by an organization, product, event or person during their life cycle. The starting of carbon management in any activity is the commencement of calculation of carbon footprint. Establishing a carbon footprint (CF) in an organization means insistence on the organization to reduce carbon emission and improve efficiency. A CF is measured in tons of carbon dioxide equivalent (tCO2e). CO2e is calculated by multiplying the emissions of each of the six greenhouse gases by its 100 year global warming potential (GWP).

A carbon footprint considers all the six of the Kyoto Protocol greenhouse gases: Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF6).

There are different varieties of carbon footprints, mainly organizations use ‘Organizational carbon footprint’ which considers emissions from all the human activities including buildings, energy usage, and industrial process and company vehicles within the organization boundaries. The second one is ‘Value chain carbon footprint’ this represents emissions from both the suppliers and the consumers, including all who use and end the life of emissions. ‘Product carbon footprint’ Emissions over the whole life of a product or service, from the extraction of raw materials and manufacturing right through to its use and final reuse, recycling or disposal.Land filling solid waste, Industrial waste water sludge, heavy metal included electronic items and hazardous chemicals are adversely affect soil pollutants. Climate change is the main baffling components in environmental cause for concern its impacts globally are quite menace us. There has been an increasing national and international concern over the accumulation of Green House Gasses (GHG) particularly CO2 and it effect on Global warming. Scientists predicted that the average global surface temperature increased by 0.6 ± 0.20 C˚ throughout the 20th century and it is projected to rise by 0.3 – 2.50 C˚ in the next 50 years and 1.4 – 5.80 C˚ in the next century. The rapid loss of forest cover in world had been a major cause of concern in terms of the environmental impacts. Natural Rubber Fertilizer input is it very low and the surrounding soil appears to be enriched by the abundant leaf fall, biodiversity due to monoculture, excellent agronomic technique and vide variety of crops during immature period, further enhance and environmental justice of credential. The forested forest area in Sri Lanka has declined from 70 percent in 1990 to less than 23 percent in early 2000. According to these figures the factual annual deforestation rate is more than 40 000 hectare per year, replanting rate is 2000 hectare per year and the population growth in the same period shows 11.5 million to 18 million.

Rubber tree crops as in the case of forest trees are known to function as natural Sponges for absorbing carbon dioxide from the atmosphere. Carbon sequestration is achieved through the uptake of carbon dioxide from the atmosphere and its conversion by plants into cellulose and organic matter. The rubber tree botanically known as Hevea brasiliensis was first planted at Henarath goda garden in Gampha such as exotic plant from Brazils many years ago from the wilderness of the Amazon basin. Later rubber tree established itself as crop for plantation agriculture. Hence, one can expect Hevea brasiliensis to behave as a typical tropical rain forest tree that would at least function as efficient as forest trees in Carbon sequestration slowdown in soil Carbon oxidation and Increase C fixation and storage. Previous studies indicated that, a rubber tree can fix about one Metric tons (MT) during its 30 year cycle. Also rubber trees add about 23 MT/hectare of CO2 to the soil through annual leaf fall, but part of which decomposes and is re cycled to the atmosphere. About 23 MT of carbon (84 MT of CO2) are removed by the trees as latex yield in 30 years. Rubber falls under ‘Cash crop-forest cover’ category contributing directly to reducing of CO2 and organically derived Natural Latex is a unique gift from Mother Nature in the form of liquid material it is tapped and collected as an environmental friendly raw material.

The world's rubber needs are met through both natural and synthetic sources (table 1) and same table denoted that each supplying nearly equal amounts.

Table 1: Rubber production 2000-2014: Natural and Synthetic

YEAR	Natural rubber	Synthetic rubber	total
2000	6811	10870	17681
2001	6913	10483	17396
2002	7317	10906	18223
2003	7986	11414	19400
2004	8726	11979	20705
2005	8921	12025	20946
2006	9850	12700	22550
2007	10057	13367	23424
2008	10098	12747	22845
2009	9723	12409	22132
2010	10395	14124	24518
2011	11217	15104	26322
2012	11639	15086	26715
2013	12251	15473	27724
2014	12070	16685	28755

Source: International rubber study group (IRSG) - cited in Natural rubber statistics, Malaysia (2015)

According to rubber industry statistics, Synthetic rubber requires petrochemicals as a feedstock for its manufacture, using roughly 3.5 times more oil than what is required for a rubber tree plantation. The most significance in Natural rubber is low energy in raw material processing and amazing effect of sequestration carbon in their life. There are many significant environmental credits of NR such as ability to lock carbon both in biomass and rubber and functioning as self-sustaining eco-system, with annual leaf fall, branches, fruit, twigs, root hairs. Its main potential lies in its significant capacity to sequester CO2 in soils, and in its synergies between mitigation and adaptation. This potential is best utilized employing sustainable agricultural practices. 'Green credentials' for natural rubber over its synthetic rivals. Some may be confused it has some hidden energy in transportation and other processing stages. When comparing raw material Energy consumption, Gigajoule (GJ)/ton, with natural rubber it is 16 (very low compared to synthetic rubber processing), Polychloroprene 120, Styrene butadiene SBR 130, polybutadiene 108, polyurethane 174, and butyl rubber 174, Polypropylene 110 GJ/ton respectively.

In developing nations like China, India and Brazil, per capita consumption of raw rubber shows an increasing trend highlighting an increased global demand for all kinds of Natural Rubber (NR) goods. The size of the world market for rubber products is estimated at $90 billion per annum which is over Rupees 116 billion per annum. Table 1 clearly described the increasing trend of rubber processing and table 2 and 3 explained that the world natural rubber market situation in last three years and the World Industrial rubber product demand respectively. The records it realized that how industry contribute on sustainable economic development.

Table 2: Summery of the world natural rubber market situation in last three years

	2013	**2014**	**2015**
Demand (millions of dollars)	26.8	28	29.2
percentage change	3.3 percent	4.1 percent	4.4 percent
Supply	12	12.3	12.6
percentage change	3.8 percent	1.9 percent	2.9 percent

Source: Freedonia group lnc. - cited in Rubber and plastic growth, (2015)

Table 3: World Industrial rubber product demand (in millions of dollars)

	2008	2013	2018	2006-2013	2013-2018
Region				PAG	PAG
North America	19500	22950	27100	5.7	6.6
Western Europe	22600	23800	27600	1	3
Asia Pacific	32900	52700	82000	9.9	9.2
Central and south America	3570	4660	6550	5.5	7
Eastern Europe	5450	6650	8610	4.1	5.3
Africa	3180	4240	6140	5.9	7.7
Total demand	87200	115000	158000	5.7	6.6

PAG- Percentage Annual Growth

Source: Freedonia group lnc. - cited in Rubber and plastic growth, (2015)

Rubber being such an important product that it had paved the way for industry providing employment to millions, one must also question its position as to how much of environmental damage it causes in relevance to other industry? However, the Rubber plantations that give us the renewable raw material for an indispensable industry unconsciously help to purify the air we breathe by removing harmful Carbon Dioxide (CO2) and indeed a major contributor in reducing Global Warming. If we can market the green image of natural rubber highlighting the true eco-friendly credentials and carbon sequestration potential of natural rubber plantations, tangible financial gains resulting in rich economies could be achieved by countries blessed with this ‘golden gift’ of a tree. Rubber manufacturing processes are based on steam obtained through burning fossil fuel and using electricity to generate power in the manufacturing process. Rubber processing beginning from Rubber cultivation and centrifuging is the next critical phase before processing the products. Organic plantation highly encourages farmers to protect environment through low emission and soil protection. Compared to conventional farming organic rubber plantation reduces their emission by 50 percent due to prohibition of chemical fertilizers.

The Primary objective of this paper is to conduct a case study to review the product carbon footprint in rubber foam processing. It evident by reduction of 50 percent of their total carbon emission due to prohibited of chemical fertilizers.

1. Literature Review

2.1 Definition and terms related to carbon-foot print

Due to the lack of a generally accepted definition of a carbon footprint there is a value to discuss about present debate of different types of terms discussed by previous studies. There is no clear evidence when and by whom the term CF was used for the first time, but it is found that in newspaper articles as early as the year 2000 used the word Carbon footprint (Biddle, 2000; Sorensen, 2000 cited byErcin and Hoekstra, 2012). Safire (2008) stressed that CF big boost to wider use of concept in 2005 and further it emphasized by Haefeli and Telnes (2005) describing now it being used in the scientific literature as well (cited byErcin and Hoekstra, 2012). As cited in Ercin and Hoekstra (2012) it described despite its popularity and use in commerce, there is no universally accepted definition of CF and today it describes the narrowest to the widest interpretation of GHG emission measurement (East, 2008; Finkbeiner, 2009; Pandey et al., 2011; Peters, 2010; Wiedmann and Minx, 2007).
The most extensive survey on the definition of the CF was done by Wiedmann and Minx (2007) and defined CF as 'The carbon footprint is a measure of the exclusive total amount of CO2 emissions that is directly and indirectly caused by an activity or is accumulated over the life' (p.6, cited by Ercin and Hoekstra, 2012). Hence, Wiedmann & Minx go beyond other definitions and considered both direct and indirect emissions, as same as that BP (2007) defined 'The carbon footprints the amount of carbon dioxide emitted due to the daily activities from washing a load of laundry to driving a car load of kids to school' In this definition also they considered both the direct and the indirect effects such as fuel burnt during the running of the car and indirect effect of electricity usage for laundry operation. Pandey et al. (2011) describe the CF as 'the quantity of GHGs expressed in terms of CO2-equivalent, emitted into the atmosphere by an individual, organization, process, product, or event from within a specified boundary'(p.6, cited by Ercin and Hoekstra, 2012).

There are different definitions that emerged the society to identify the word carbon footprint proposed by the Parliamentary Office of Science and Technology (POST) 'A carbon footprint' is the total amount of CO2 and other greenhouse gases, emitted over the full lifecycle of a process or product. It is expressed in terms of grams of CO2 equivalent per kilowatt hour of generation (gCO2eq/kWh), which accounts for the different global warming effects of other greenhouse gases (POST, 2006). Global Footprint Network (2007) also elucidated it in technical manner as 'The demand on bio capacity required to sequester (through photo synthesis) the carbon dioxide (CO2) emissions from fossil fuel combustion'. They concentrate it on the offsetting aspect only and a problem is why they considered only the CO2 emissions and fossil fuels burning. According to their definitions they mainly concentrate only on the emission and sequester trees, but they are not plainly distinct on other activities which can be implied to minimize emission or other offsetting targets because the aforesaid definition referred to by the Energetics (2007) with referred to the 'The full extent of direct and indirect CO2 emissions caused by the business activities'. As same as defined Grub & Ellis (2007) carbon footprint is a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels and in the case of a business organization, it is the amount of CO2 emitted either directly or indirectly as a result of its every day operations. This also might reflect the fossil energy represented in a product or commodity that reaches the market.

Carbon trust (2007) defined it as 'a methodology to estimate the total emission of greenhouse gases (GHG) in terms of carbon equivalents from a product across the stagers of its lifecycle from the production of raw material used in its manufacture, to the disposal of the finished product (excluding in-use emissions)'. A technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain processes is that depend on the frame work for attributing these to each output product. The Carbon Trust, (2008) will refer to this as the product's 'carbon footprint'. Further they referred to it in 2008 as, 'the term carbon footprint is commonly used to describe the total amount of CO2 and other greenhouse gas (GHG) emissions for which an individual or organization is responsible'. Hence the Author is confused with why they have not mention up to which extent that means the boundary and organization, if they are responsible for better clarification as to what extent. Based on the above definition author realized that difficulty to select a one definition from above due to lack of concepts inherent in definitions.

Hence the author emphasized that in any proper definition, It should have included in definitive team as to which category of gases are included in the calculation, what is the best boundary, what kind of emissions which we are going to consider and carbon management targets.

2.2 Methodologies involving in Product carbon footprint

It is critical to discuss about different methodologies involved with product carbon footprint and their differences to one another. Still there is a little uniformity in calculation process used by different standards. The main differences highlighted in literature are explained as, scope of study, gases included in the calculation, the weighting of gases to arrive at CO2-equivalents and the system boundaries. When discussing about product footprint it is still not a properly agreed standard and there are different varieties of standards that have been published by several organizations. The Publicly Available Specification 2050 is the first standard introduced by the British Standards Institution in 2008 and updated again in 2011(BSI 2011). This method has affected their calculation base on LCA approach especially for the goods and services. ISO 14067 is a currently developing standard for measuring product carbon footprint. Other ISO standards related to the CF are ISO 14040 on Life Cycle Assessment (ISO, 2006*a*) and ISO 14064 on Greenhouse Gases (ISO, 2006*b*).

2.3 Scope selection and Carbon footprint calculation

2.3.1 Scope selection in Product carbon footprint

Once a company has determined its organizational boundaries, it is important that categorizing them as direct and indirect emissions, and finally choosing the scope of accounting by considering indirect emissions. Direct GHG emissions can be categorized as emissions from sources that are owned or controlled and Indirect GHG emissions are emissions which could own or controlled by another company. There are three defined scopes for GHG accounting and reporting purposes. Emissions from chemical production in owned or are controlled process equipment, emissions from combustion in owned or controlled boilers, furnaces, and vehicles can be considered under scope 1 emission. Kyoto Protocol has not considered all greenhouse gases such as CFCs, NOx, etcetera are not covered as greenhouse gases but it should be reported separately. Direct CO2 emissions from the combustion of biomass shall not be included in scope 1, but it is also reported separately. Scope 1 considers only the direct greenhouse gases and it is not covered under indirect effects. Scope 1 emissions generated in companies due to different activities are named as generation of electricity, heat, or steam from combustion of fuels in boilers, furnaces, turbines, in manufacture of or processing of chemicals and such materials as cement, ammonia manufacture, and waste processing, Transportation of materials, products, waste, and employees etcetera.Scope 2 GHG emissions are produced from the generation of electricity purchased and used by the company.

Companies can reduce their application by different technologies and energy conservation projects. Energy audits are also a very effective technique for controlling energy in organizations. Mini hydro -plants, solar techniques, wind mills and sea wave energy are used by organizations to mitigate this problem to a certain extent. Scope 3 is considered all other indirect emissions but occur from sources not owned or controlled by the company such extraction and production of purchased materials and fuels, transport-related activities, electricity-related activities not included in scope 2, leased assets, franchises, and outsourced activities, use of sold products, services and waste disposal. However, the most common approach for calculating GHG emissions is through the application of documented emission factors.

Through collected activity data and chosen emission factors for the most small to medium-sized companies and for many larger companies, Scope 1 GHG emissions will be calculated based on the purchased quantities of commercial fuels (such as natural gas and heating oil) using published emission factors. Scope 2 GHG emissions will primarily be calculated from metered electricity consumption and supplier-specific, local grid, or other published emission factors. Scope 3 GHG emissions will primarily be calculated from activity data such as fuel use or passenger miles and published or third-party emission factors. In most cases, if source- or facility specific emission factors are available, they are preferable to more generic or general emission factors. These include stationary combustion, mobile combustion, HFC use in refrigeration and air conditioning, and measurement and estimation uncertainty. Sector-specific tools that are designed to calculate emissions in specific sectors such as aluminum, iron and steel, cement, oil and gas, pulp and paper and office based organizations. The main difference which we can observe in the CF calculations is very important to discuss in the finalizing and comparison process of CF.

There are some deviations that we observable in calculations such as selection, the scope of the study in this process and indirect emissions are often excluded and the gases included as well as this not yet finalized for further the weighting of these gases to arrive at CO2-equivalents is still being discussed among world organizations and the other critical aspects that have to be discussed is the system boundaries chosen to determine how to truncate the analysis of emissions in the supply chain.

Ercin and Hoekstra (2012) have mentioned that at the product level, CF specification still not has finalized the proper standard. In the meantime some organizations have published their own guidelines and standards. The *Publicly Available Specifications 2050* of the British Standards Institution was one of the first standards describing calculation methods for product CFs and they were first published in 2008 and updated three years later (BSI, 2011 as cited Ercin and Hoekstra 2012). This standard describes the calculation of GHG emissions of goods and services based on the LCA approach. In the same report author mentioned that wide use other standards are the GHG Protocol *of* the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Further they have considered that 'ISO is currently developing a product CF standard known as ISO 14067, ISO 14040 and ISO 14064. The Japanese Industrial Standards Committee also published a *Basic Guideline of the Carbon Footprint of Products* (JISC, 2009).

2.3.2 Carbon footprint calculation methods

There are three different types of calculation methods for CF, norm they are bottom-up, top-down and hybrid approaches (Matthews et al., 2008; Peters, 2010; Wiedmann & Minx, 2007).The bottom-up approach is based on LCA, a method that estimates the environmental impact of products by 'cradle to grave' analysis. This method is mainly used for estimation of the CF of products and small entities (Peters, 2010; Schmidt, 2009; Weidema et al., 2008). The top-down approach is used for calculating the CF of large entities such as sectors, countries and regions. Input-Output Analysis (EE-IOA) is the main method for top-down. The hybrid approach to CF accounting combines the specificity of process analysis (using LCA) with the system completeness of EE-IOA (Lenzen & Crawford, 2009). This approach retains the details and the accuracy of the bottom-up approach (which is especially relevant in carbon-intensive sectors). In the hybrid approach, the first and the second-order process data are collected for the product or service and higher order requirements are covered by input-output analysis (Wiedmann and Minx, 2007).

The methodologies for carbon footprint calculations solve as important tools for greenhouse gas mitigation. The concept of product carbon footprint is commercialized by industries and several other authorities, but there is confusion in deferent stagers and still there is no clear-cut definition. In the process of calculation there are different methods, different methodologies and there is no proper stranded or much disagreement in greenhouse gas selection in calculation. The Present review describes the prevailing carbon foot printing methods and raises the related issues. The primary objective of this paper is to distinguish between organic and non-organic effects in manufacturing rubber based products and to describe how process activities contribute to generate product carbon footprint in the manufacture of rubber based products. The ultimate objectives of paper is to discuss, to what extent manufactures are concern about their own that effect PCF, in order to evaluate factors effecting PCF, to identify the core process that contribute very much into product carbon footprint and to identify top management commitment with regard to reduction targets.

2.4 Different types of carbon footprint logos

There are different types of carbon logos in businesses, such as Casino Carbon Index, Climate award for low carbon, best in class products, Carbon trust reduction logo and certified carbon free- Carbon neutral label.

Casino logo is related to the product carbon foot print, and it has referred the calculated product carbon footprint together with a benchmarking scale. The core purpose of this logo is to create awareness the mind of the consumers on the subject of transparency and to enable them to take informed decisions on climate-aware consumption. The Casino Carbon Index is symbolized by a green leaf and displayed in grams CO2e per 100 g of product on the front side of the package. Casino plans to label all the 3000 food products that they offer with the Casino Carbon Index and currently 32 different products are labeled. Climatop award for low carbon logo designs based on product carbon foot print and it has not mentioned the amount of emission which is described in the above as Casino Carbon index. That gives an indication that the product belongs to the best in classed products concerning PCF without showing any figures. It has to show the cause significantly that lower CO2 emissions during its life cycle compared to relevant goods or services of the same category. This logo is very useful and easy to take decision in the point of purchasing products.

This logo base on LCA data and product can only be labeled if it has an at least 20 percent lower CO2e emission than their comparable products of its product group. Carbon trust reduction logo belongs to Carbon trust foot printing company and uses PAS2025 methodology for calculations. This logo very clearly mentions that calculated product carbon footprint and plan or achieves reductions in future to reduce the carbon footprint over the following two years. The label shows the total greenhouse gas emissions in grams per indicated functional unit from every stage of the product's lifecycle, including production, transportation, preparation, use and disposal. If the company has not or had been achieving the target within two years, then they do not allow them to use the label. This labeling is very critical because it indicates total greenhouse gas emission related to total life cycle of product. Certified carbon free- Carbon neutral label also displays the PCF. This logo concerning the methodology for the calculation of the carbon footprint Carbon fund refers to the WBCSD/WRI Protocol.

2.5 carbon markets

There are two different types of carbon commodities, which can be categorized as allowances and offsets. The first allowances is created by cap-and-trade system and the second, offsets are created by baseline-and-credit systems (a project-based system).

2.5.1 Cap-and-Trade Systems

Kollmuss et al. (2008) suggested that based on an emission reduction targets cap and trade system is allocated a certain number of allowances from overall cap. This system drives within actors in a cost effective way to reduce their emissions and internalize the cost of emission. The most critical criteria here are these allowances which are then neither created nor removed, but merely traded among participants. In 1997, United Nations Framework Convention on Climate Change (UNFCCC) established a Kyoto protocol which was passed by 2012 (Dayaratne and Gunawardana, 2015). The same paper which emphasizes how Kyoto protocol produced an agreement to join with a few different countries to reduce the greenhouse gas (GHG) effect from 5.2 persent emission as from 1990 level during the period of 2008-2012. Dayaratne and Gunawardana (2015) cleared the three mechanisms involved in Kyoto protocol such as Emission trading, joint implementation and cleaner development mechanisms. Under the Clean Development Mechanism (CDM) it is divided into two parts, such as the first and the second which were limited to industrialized countries the third was introduction of projects in developing countries.

The Kyoto Protocol has not been able to collect a group of many countries to join together in the setting of overall caps. The 15 original member states of the EU formed a group and it was named as EU Emissions Trading Scheme (EU-ETS) in 2005 and it operates independently. Researchers suggested that in 2006, it earned over €16 billion by traded 1 .1 billion metric tons of CO2e. Example for other independent programs running for emission trading as New South Wales GHG Abatement Scheme (NSW GHGAS), established in 2003, Regional Greenhouse Gas Initiative (RGGI), they mentioned to start in 2009 but stabilization of emissions at current levels (an average of 2002-2004 levels) by 2015, they are planning to reduce 10 percent during 2015-2020 and the main off set projects were undertaken in the electricity sector. Western Climate Initiative (WCI)is a collaboration of 5 Western US states and British Columbia which was launched in early 2007. They set targets to reduce greenhouse gas by 15 percent of 2005 levels by 2020.

2.5.2 A baseline-and-credit system

Though this does not involve projects more credits are generated with each new project and these credits can be traded by buyers to comply with a regulatory emission target, to offset or neutralize (carbon neutral) any activity with zero ‘net’ emissions. Clean Development Mechanism (CDM) provides much more opportunities for industries which not involve in industrial development and expansion and their core objective is to emphasize the sustainable development in countries. Cleaner production activity addressing pollution during the process and its aspired outcome is to reduce energy and waste ensure better quality, engagement more recycling, envisage good environment and proper practices bestow customer satisfaction and so on. In this way, the country can earn saleable certified emission reduction credits (CERs). Develop emission reductions projects in developing countries because those countries generally are more cost effective due to average lower energy efficiencies, lower labour costs, and weaker regulatory requirements and less advanced technologies. Joint Implementation (JI) is also another kind of initiatives in emission reduction or limitation. JI exhorts to one country can earn emission reduction units (ERUs) from an emission reduction or emission removal projects in another countries. Joint Implementation functions similarly to CDM; nonetheless the host country does not need to be a developing region but it should be an adjoined the country. The selling unit from JI projects is known by Emission Reductions Units (ERUs).

The third are mechanisms that allow countries to earn removal units (RMUs) through projects that sequester CO2, such as reforestation. CERs, ERUs and RMUs are all communicated in CO2-equivalents and traded on the carbon market and countries buy carbon credits to meeting its Kyoto target. The value of both JI and CDM projects has more than doubled in recent years, reached USD 5 billion (EUR 39 billion) in 2006 It highlighted that 90 present of the credits transacted in these markets were produced by CDM projects because JI officially started in 2000.

3.0 Methodology

3.1. System Boundary

The system boundary for the assessment is cradle-to-grave and the simplified process map (Figure1) illustrates the key processes and activities in the life cycle of the products assessed. For each life cycle stage the following generic emission sources and sinks were considered, and where relevant, the associated emissions were quantified, with reference to embodied emissions of raw material inputs, Electricity use, Stationary fuel combustion, Mobile fuel combustion, Land use change, Emissions from waste disposal, Other fugitive emissions (e.g. refrigerator leakages) and emissions due to use of fertilizer and pesticides.

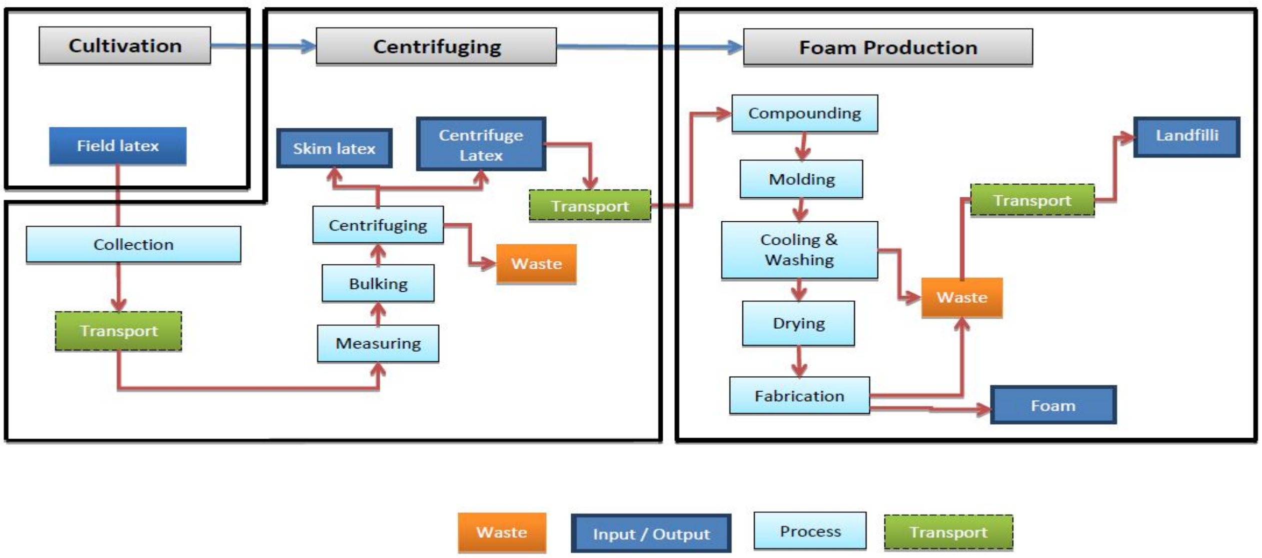

Figure 1: Process flow map for foam manufacturing

Source: Author's own elaboration

Emission sources or sinks which were excluded from the scope of the assessment, in accordance with the requirements of PAS 2050, were Changes in soil carbon, Emissions associated with the production of capital goods, Human energy inputs to processes, Transport of consumers to and from the point of retail purchase, Transport of employees to and from their normal place of work, Animals providing transport services, Further, embodied emissions and emissions in the use phase of Kieserite Fertilizer in rubber plantations also excluded due to the lack of available data. Data collection was carried out by consultants of Control Union.

3.2. Data Collection and Quality

Data collection was carried out by the consultants of Control Union. After initial site visits and after communications primary data were collected for following sites:

- Latex Green Pvt Ltd (Foam manufacturing factory)
- Ellawala Rubber (Pvt) Ltd (Centrifuging facility)
- Lak Latex (Centrifuging facility)
- Paklan Latex (Centrifuging facility)
- Mohomad Estate – Baduraliya
- Horagoda Estate – Baduraliya
- Putupawula Estate - Naboda

Input material contribution from each centrifuge factory to foam factory is illustrated as 59 percent from paklan, 28 percent Lak latex and 13 percent from Ellawala latex.

Monthly electricity, fuel and chemical consumptions were obtained from the factory refereeing to purchasing and billing records. From standpoint of process of electricity and fuel consumption details of foam factory were obtained after referring to the energy audit report carried out in 2014. There has been no change in the production facility or the production process from 2010. Assumptions and guidance's utilized to obtain data in cases where there were not sufficient evidence to cover data. (E.g. COD value of the inlet wastewater treatment plant). Data gaps were filled after contacting Latex Green coordinator to improve the accuracy and completeness of data. The PAS 2050 requires that primary data is provided for all emission sources directly owned or operated by the reporting organization, and that 10 percent or more of total upstream emissions are covered by primary data. Determining the proportion of emissions covered by primary data is not straightforward, for example, emissions are often calculated using a combination of primary and secondary data, and precise guidance on determining the proportion is not given in the PAS.

3.3 Emission Factors

The most geographically relevant and up-to-date emission factors were used for the assessment. The sources for emission factors include the Intergovernmental Panel on Climate Change (IPCC), Revised IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (IPCC, 2006), Defra's Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting (DEFRA, 2013), and the International Energy Agency's National electricity grid-mix emission factors and compositions. All emission factors used in the assessment are detailed throughout the calculation sheets in Appendix II, and the references are provided in the References section. The global warming potentials (GWP) used in the assessment are from the IPCC Fourth Assessment Report (IPCC, 2007).Electricity grid emission factor which was chosen from IEA 2013 and it relates to 2011 emissions.

4.0 Result and Discussion

4.1 Desk information and response from experts

Author conducted a construct interviews with industry experts to collect relevant information for mitigation of carbon foot print in Life cycle of product base on Supply chain. There are different comments and arguments created through discussions. Some leaders in Rubber industry, there strongly believed there is no proper standard or policy for carbon mitigations in industry level. But every organization now concern about pollutions and environment more than ever before due to protect them through given targets. Few leaders suggested, carbon foot print is a window dressing in organization within a given frame work to achieve marketing agendas in business, no genuine commitment to society.

Organization which are leading in field or rubber base manufacturing those are still not much aware about greenhouse gas emission of products which there produced, because in the point of export it's not a big damage for them or no big competition when comparing to textile or apparels products. Some of leaders clearly suggested that carbon footprint is not a compulsory for organizations to control under environmental norms, therefor if an organization would voluntary engaged with this kind of activities, and then it will add values to them in the sense of customer satisfaction or marketing. Some of them commented that industries not ignoring carbon emission due to supply chain, but there is not properly set standard to reduce emission given by government or authorities.

After finished interviews with industry leaders, author realized that there are different kinds of driving forcers for desired change (Greenhouse gas effect due to product life cycle) and some restraining forces that blocking the change. Base on collected information author drawn a Force field analysis table to get clear understanding about new concept of Product life cycle emissions.

Force field analysis is a problem-solving tool used to help change occur. It was first used during World War II by Kurt Lewin, a professor at the University of lowa. Force field analysis, as used by Lewin, views change as a struggle between forces. Driving forces are those forces that help the change occur. Restraining forces are those forces that are affecting a blockade on the change. Force field analysis is the exercise of identifying the driving and restraining forces that surround a proposed change. Working through this process of identifying forces that encourage creative thinking by forcing a team to think together about the aspects of the desired change. The exercise also encourages the team to agree on the priority of the forces. This agreement provides a starting point for action. Lewin identified three possible change strategies of using force field analysis, a team can choose to increase the driving forces, decrease the restraining forces, or do both.

Increasing the driving forces can have the unexpected result of reinforcing the restraining forces. Lewin suggests that the best way to help the change occur is to decrease the restraining forces. When taking action to decrease a restraining force, the restraining force often becomes a driving force. Force field analysis is used by teams when trying out their improvement theories. It is often used just after the team has generated improvement theories using nominal group technique. It is a powerful tool and can be used to help any change occur. The author summarizes the collected information base on Expert's comments. They had discussion on those driving forces which encourage organizations to go beyond green and some restriction forces that would adversely affect the change. Discussing driving forces and determining their relative importance: Forces can be prioritized by using several different methods: forced ranking, an open discussion, or a vote, maximum is six marks. Use the same process as in the above step to prioritize the relative importance of the restraining forces maximum marks is seven. According to force field analysis, it revealed that restraining forces are more on the increase compared to driving forces. It is very clear by seen in table 4. According to the above diagram it is clear that the expect of restraining forces is higher than the driving forces. The outcome of the diagram is very similar to that of the experts which transpired at the discussion.

Table 4: Driving and restraining forces related to reduction of greenhouse gas emission in product lifecycle

Driving Forces (+)	Restraining Forces (-)
Conduct and energy audits and implement electricity controls	No proper established policy
Introduce bio mass boilers for steam generation	Huge investment for changers
Reduce emissions from raw material stage	Reluctant to change
Minimize other gasses emissions	No top management support
Management awareness programs and training of employees	Organization not allow for money for green activities
Increase sales	No financial benefits
Attitude of owners	Roll of the government

Source: Author's own elaboration

4.2 Primary data analysis

Total emissions during the cradle to grave emissions assessment listed in Table 6. Emissions were allocated to process when there were reliable data. Total product footprint was calculated as 6.67 kg CO2e per kg of foam produced. This is the value after allocating emissions during rubber cultivation, centrifuging and as well as foam manufacturing.

4.2.1. Cultivation, centrifuging and foam manufacturing

The only notable and emission in the cultivation phase of rubber is the in-organic fertilizer applications. Generally Nitrogen: Phosphorus: K (with ratios of 12:14:14, 18:06:24) is used in all rubber fields with only additional Mg inputs in the form of Keiserite for fields supplying to Ellawala Centrifuge Plant. Emissions related to fertilizer are resulting of both embodied emissions of the fertilizer and also the use phase in the rubber plantations. As per the field data, only one application is done per year per tree.

The quantity of application differs in each site. Since the three centrifuging plants have different centrifuged latex contribution to the foam factory, the emission as per allocation from each centrifuge factory is calculated. Each centrifuging facility has different process emissions depending on the production quantity, material uses and the use of electricity (power generators) as indicated in the comparison of process emissions by each centrifuging facility is illustrated in table below. As per the results, most sustainable centrifuged latex provider among the three centrifuged latex suppliers is Paklan Latex. The major contributing factor has been that the fields supplying to Paklan has used the least amount of fertilizer in cultivation. Table 5 summarizes the product carbon footprint for the functional unit of 1 kg of 100 percent natural foam considering 100 percent input material supply from each centrifuge plant. Total emissions during the cradle to grave emissions assessment in Base year and 2014 are listed in Table 4. Total product footprint was calculated in 2014 as 6.67 kg CO2e per kg of foam produced. Total carbon emissions in producing 1kg of foam is increased by 5.07 percent due to the increase in electricity consumption and other inputs in centrifuging and foam manufacturing processes.

According to the comparison between Base year and 2014, only emissions from cultivations showed net reduction of 0.06 kg of Carbon Dioxide equivalent in producing 1kg of foam due to the changes in centrifuged latex contribution by three different centrifuging plants. Contrary to cultivations, the other two processes showed net increase in the total carbon emission values. Among them, emissions in foam production process showed notable increase of 12.63 percent due to the increase of electricity and furnace oil consumption during foam manufacturing.

Table 4: Comparison among three latex supplier's emission levels-from cradle to grave-Non organic

Centrifuged plant	Emission to produced 1 kg of foam (kg CO2 e/ kg of foam)			
	Cultivation	Centrifuging	foam manufacturing	Total emission
Ellawala	4.736	0.5018	3.0062	8.2441
Packlan	1.465	0.6628	3.0062	5.134
Lak latex	5.8956	0.3506	3.0062	9.2525

Source: Author's own elaboration

Table 5: Total emission in cradle to grave of 1 kg of foam-Non Organic

Process	Emission type	Emission kg CO2e/kg of foam
Cultivation	Fertilizer-Upstream (cultivation)	1.589
	Fertilizer-Use (cultivation)	1.5231
Centrifuging	Field latex transportation	0.286
	Grid electricity consumption	0.0357
	Use of power generator	0.0009
	Transport and use of machine oil	0.0087
	Use of chemicals (ammonia)	0.1538
	Centrifuged latex transportation	0.0708
Foam production	Emission at compounding	1.0593
	Emissions at moulding	0.0426
	Emissions at cooling and washing	1.5509
	Emissions at drying	0.0123
	Emissions at fabrication and finishing	0.0371
	Emissions by other electricity uses	0.2048
	Emissions by waste disposal	0.0067
	Emissions by waste water treatment	0.0025
	Emissions by use of fork lift	no
	Emissions by use of power generator	0.0244
	Emissions by use of packing material	0.0047
	Emissions by use of machine oil	6.6734
Total emissions in producing 1kg of foam		6.6734

Table 6 clarifies the emission due to non-organic verses organic foam manufacturing showing that is doubled compared to organic foam. Emissions accounted at the cultivation stage are the emissions due to the application of fertilizers. The value **6.67 kg CO2e** means during the process of cultivation to manufacturing of 1 kg of 100 percent natural latex foam it will have 6.67 times impact than 1 kg of CO2 would course during a period of 100 years after manufacturing. The value 3.336 kg CO2e means during the process of cultivation to manufacturing of 1 kg of organic latex foam it will have 3.336 times impact than 1 kg of CO2 would cause during a period of 100 years after manufacturing. That means non organic foam emissions double due to fertilizer application in rubber plantation. Figure 1 clarifies that both centrifuging and foam manufacturing process do not show differences in emission levels.

5.0 Conclusion

It is clear that application of fertilizers during the cultivation would double the emissions in the final product. It further revealed that carbon emission in one kg of foam contribute and to global warming of 47 percent due to cultivation, 45 percent due to foam production and 8 percent due to centrifuging, which are the three stages involved in manufacturing of rubber latex foam.

When it comes into foam manufacturing process, GHG emissions due to drying is 52 percent, moulding 35 percent and 8 percent due to waste disposal and the rest due to transportations, waste water treatment and other activities and with reference to centrifuging of latex, the emission generated increased to 50.49 percent in due to chemicals used in the process and the rest used for transportation and power generation.

Table 6: Comparison between Non Organic verses Organic

Description	2014-Non organic		Description	2014-organic	
	CO2e(kg)	percentage		CO2e(kg)	percentage
Cultivation	3.11	46.63%	Cultivation	0	0.00%
Centrifuging	0.56	8.33%	Centrifuging	0.399	11.97%
Foam manufacturing	3.01	45.04%	Foam manufacturing	2.936	88.03%
total	6.67	100%	total	3.336	100%

Source: Author’s own elaboration

These findings could be of immense use for countries involved in rubber plantations and downstream manufacturing industry those that contribute to increase emissions and to establish offsetting targets that are very useful to create a carbon free society through socio-economic developments. Company will continuously maintain its carbon neutrality during 2015-2020 periods by offsetting 93 percent of carbon footprint calculated in each year after achieving 7.24 percent of emission reduction target. Company aims at continuously reducing GHG emissions from its operations. During the product carbon footprint assessment, it was identified that cultivation process is the main contributing factor to company’s total carbon emission. However, foam manufacturing process is under direct control of the company, emission reduction opportunities which involves in foam manufacturing can be achieved easily and effectively. Year 2016 company is forecasting to convert conventional rubber plantation in to organic by 50% to achieve reduction targets set by offset planning. Force field analysis reviled that restraining forces are high compared to driving forces for product carbon foot print implementation. Expert comments were concluded with the impotency of carbon foot print analysis for future survival in industry and requirements of reduction strategies. Future every organization should have to take responsibility to reduce their emissions in supply chain. Process level emissions and chemical usage is very critical in emission reductions. Industry leaders should pay their attention on that subject and better to encourage managers for environmental activities for protection of planet from climate change and greenhouse gas effect.

References

British Standard Institute, (2011). *PAS 2050,* UK.

BP, (2007), what is a Carbon Footprint: http://www.bp.com/liveassets/bp_internet/globalbp/ STAGING/global assets/downloads/A/ABP_ADV_ what_on_earth_is_a_carbon_footprint.pdf

Carbon N Zero, (2008), Glossary of commonly used terms, Land care Research. [Online] Available: http://www.carbonzero.co.nz/glossary.asp (10th July 2015)

Carbon Trust, (2007), Carbon Footprint Measurement Methodology, The Carbon Trust, London, UK. [Online] Available: http://www.carbontrust.co.uk (27th February 2007)

Carbon trust, (2008), [Online] Available: http://www.carbon-label.co.uk/ (11th of July 2015)

Department of Climate Change 2008a, National Greenhouse Accounts Factors, Australian Government, Canberra

DEFRA Act on CO2 carbon calculator (2013). http:// actonco2.direct.gov.uk (11th JULY 2015).

Ercin, A., E., & Hoekstra, A., Y., (2012), ‘Carbon and Water Footprints Concepts, Methodologies and Policy responses’, united nations world water assessment programme, Published by the United Nations Educational Scientific and Cultural Organization , Paris.

Energetics, (2007), The Reality of Carbon Neutrality, London.[Online] Available: www.energetics.com.au/file?node_id=21228(11th of July 2015)

GFN, (2007), Ecological Footprint Glossary .Global Footprint Network, Oakland, CA, USA, [Online] Available: http://www.footprintnetwork.org/gfn_sub.php(11th of July 2015)

Grubb and Ellis, (2007), Meeting the Carbon Challenge: The Role of Commercial Real Estate Owners, Users & Managers, and Chicago.

Houghton, J. T., Jenkins, G. J. & Ephraums J. J. (eds.) (1990).*Climate Change: The IPCC Scientific Assessment.* Report prepared for the Intergovernmental Panel on Climate Change by Working Group I. Cambridge, UK, Cambridge University Press

ErtugErcin & Arjen Y. (2012). Hoekstra Carbon and Water Footprints Concepts, Methodologies and Policy Responses, United Nations world water assessment programme, published by the United Nations Educational, Scientific and Cultural Organization7, place de Fontenoy, 75352 Paris 07 SP, France

ISO, (2006a), ISO 14064-1:2006, Greenhouse gases part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals, [online] Available: http://www.iso.org/iso/catalogue_detail?csnumber=38381 (17th October 2015)

ISO, (2006b), ISO14064-2:2006, Greenhousegases—Part2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements, [online] Available: http://www.iso.org/ iso/iso_catalogue/catalogue_tc/catalogue_detail.htm? csnumber=38382 (17th October 2015)

ISO (1999), International Standard on Environmental Performance Evaluation, (ISO 14031), International Standard Organization, Geneva

IPCC (2006). National Greenhouse gas inventories: Land use, land use change and forestry. Hayama, Japan: Institute of Global Environmental Strategies.

IPCC (2007), Climatechange2007: Synthesis report: Contribution of working groups I, II and III to the fourth assessment report. Inter-governmental Panel on Climate change.

Koll muss, A., Zink, H. and Polycarp, C. (2008). Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards. Frankfurt, WWF-Germany.

Lilly white, R, Chandler, D, Grant, W, Lewis, K, Firth, C, Schmutz, U &Halpin, D (2007).Environmental Footprint and Sustainability of Horticulture (including Potatoes) – A Comparison with other Agricultural Sectors, Welles Bourne, United Kingdom.

National Greenhouse Gas Inventory Committee, (2007), Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks (2006), Agriculture, Department of Climate Change , [Online] Available: http://www.climatechange.gov.au/inventory/methodology/pubs/methodologyagriculture2006.pdf (10th July 2015)

Matthews, S. C., Hendrickson, C. T., & Weber, C. L. (2008b).The importance of carbon footprint estimation boundaries. Environmental Science and Technology, 42(16), 5839–5842.

Natural rubber statistics, Malaysian rubber board, (2015), [Online] Available: http://www.lgm.gov.my/nrstat/nrstats.pdf (14th October 2015)

Padgett, J. P., Steinemann, A. C., Clarke, J. H & Vandenbergh M. P (2008).'A comparison of carbon calculators', Environmental Impact Assessment Review, vol. 28, pp. 106–15.

POST, Carbon footprint of electricity generation, POST note 268, Parliamentary Office of science and Technology, London, UK,(2006), [Online] Available: http://www.parliament.uk/documents/upload/postpn268.pdf

Peters, G. P. (2010). 'Carbon footprints and embodied carbon at multiple scales, Current Opinion in Environmental Sustainability', Vol. 2, No. 4, pp. 245–50.

Rubber and plastic growth, (2015), [Online] Available http://www.rubbernews.com/article/20150129/NEWS/301269980 (14th October 2015)

Dayarathna, S. P. & Gunawardana K. D., (2015).'Carbon footprint reduction: a critical study of rubber production in small and medium scale enterprises in Sri Lanka', vol., 103, pp. 87-103.

TreeVestors, Green glossary, Tree Vestors, (2008), [Online] Available: http://www.triplepundit.com/pages/carbon-marketterminology-deci-003010.php (8th July 2015)

Wiedmann, T., & Minx J., (2007).'A Definition of Carbon Footprint'. Durham, UK, ISAUK Research & Consulting.

World Resource Institute & World Business Council for Sustainable Development (2008), the greenhouse gas protocol: a corporate accounting and reporting standard, The Greenhouse Gas Protocol, viewed 8th August (2015), [Online] Available :http://www.ghgprotocol.org/files/ghg-protocol-revised.pdf (15th October 2014)