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Carbon footprint reduction: a critical study of rubber production in small and medium scale enterprises in Sri Lanka

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ABSTRACT

In response to the winds of change world over, as a result of rapid advance in science and technology, it has strengthened the Small and Medium Scale Enterprises (SMEs) to exert themselves as engines of their economy in the sphere of production as a whole economy as well as increase of production and competition in the market. This situation is augmented as a result of consumer demand. Its impact is such that we discern a rapid increase of population, urbanization, social mobility and transition with vigorous competition. Looking at opportunities to maximize production to satisfy customer needs, SMEs do not consider the factors that affect environment during manufacturing process, selling and distribution and consumption stages. Considering the magnitude of the excessive toxic effect on the biosphere and in order to protect the natural environment for the sustenance and conservation of organisms, it is imperative for all the parties concerned to take up responsibility to include carbon footprint mitigating measures during industrial processes. Available literature revealed that different types of systems have been set up to minimize carbon footprint by the industry at both national and international levels, but still there are issues on identifying carbon footprint usage and emission levels along with implementation systems/methodologies introduced. Researchers identified energy consumption being largely associated at the rubber mill and emissions are extraordinarily connected to productivity of kW/H of energy consumption. In order to carry out research goal barriers in implementing energy-efficient carbon footprint minimization measures, responses to one hundred questionnaires were collected from rubber product manufacturing SMEs registered under the Ministry of Industry and Commerce, Sri Lanka. Twenty five unstructured interviews were conducted with relevant professionals in order to ascertain their opinion. There are vital findings in this research — mainly the correlation of factors affecting relationship on minimizing energy efficient carbon footprint effects which will phase-in obliging emphasis on policy makers to rethink their planning. This was proved by using the fishbone model. Major barriers were identified by using content analysis of respondents. In order to identify the CO_2 emission level, the researcher examined the calculation model developed from the results to quantify carbon emission level from the three rubber-band manufacturing factories that were selected as case study domains. Case-studies revealed the overall emissions from the production of rubber band amounting to 1.16, 1.53 and 1.23 ton CO_2-eq/ton product respectively. These findings could be directly benefited by any country where rubber production is being put into practice; in order to identify factors that would minimize global warming potentials of rubber manufacturing SMEs, by the application of cleaner manufacturing model to achieve sustainable production.

1. Introduction

As a result of the marked deterioration of climate change and its impact identified by the scientists, in the 1990s World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) formed Inter-governmental Panel on Climate Change (IPCC) to identify further issues and promote awareness campaigns to address this felt-need of eco-friendliness/eco-society. Greenhouse gas (GHG) emissions mainly consist of Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydro Fluoro Carbon and per Fluorocarbons (HFCs, PFCs) respectively as well as Sulphur Hexafluoride (SF_6) emissions from manufacturing process reactions, distributions and treatment processes (Verfaillie and Bidwell, 2000 cited by Shi et al., 2012). Approximately eight billion

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tons per year of carbon in the form of CO_2 are emitted globally through the burning of fossil fuels during transportation and for the production of thermal heat and electricity worldwide. According to IPCC (2007), Senge (2008) cited by Shi et al. (2012) and Röös and Tjärnemo (2011), this is about five billion tons more than the absorptive capacity of the biosphere. In 1997, United Nations Framework Convention on Climate Change (UNFCCC) came into existence as a result of the intervention of Conference of Parties (CoP) and established a Kyoto Protocol which phased out by 2012. This was the legal binding process and agreement was those countries themselves combined as a joint venture to reduce the GHG by 5.2 percent emission as from 1990 level during 2008–2012 periods. In the agreement they have three mechanisms established: Emission Trading, Joint Implementation and Clean Development Mechanism were the organizations that formed the Kyoto Protocol. Under the Clean Development Mechanism (CDM) it has divided itself into two sub-sections in sequence (i) the first and the second were limited to industrialized countries (ii) third was introduction of projects in developing countries in order to introduce sustainable development.

At the Earth Summit held in 2012 in Rio de Janeiro, all the participant countries reached consensus were: common vision, renewing political commitment, green economy in the context of sustainable development and poverty eradication, institutional framework for sustainable development, framework for action and follow-up and means of implementation. The other main focus of this summit was to identify how to support human development and environmental conservation (The Global Transition – The Green Economy, 2012). Plainly, all manufacturing processes emit carbon and the amount depends on the input and production capacity of machinery. In the course of the continuous functions of industries, it is imperative that, the industries have to ensure eco-friendliness in the environment with provision for clean water, clean air and the mineralization of wastes. In order to minimize harmful impact on the environment, ISO standards were introduced. Certified management standards also came into existence for ensuring of the worker-health and safety.

Jegannathan and Nielsen (2013) stated that, industries around the world are thus looking for alternative technologies that can deliver the increasing numbers of products in demand every year while consuming fewer resources and having a lesser impact on the environment.

During all the stages in the manufacturing processes of rubber products, it consumes a high quantity of energy, water and other natural resources. It being the ever-booming industry, rubber will count as a carbon emitting product which cannot be evaded though the latex is drawn from rubber tree. Therefore it is absolutely necessary to identify carbon footprint mitigating measures to ensure sustainable business in practice on a commercial scale. Enormous potential exists for cost-effective improvements in the existing energy-using equipment. Also, application of good housekeeping measures could result in appreciable savings of energy by the parties concerned in respective governments and especially, at plant level in the industries.

The main electrical energy users in rubber milling process are motors and drives, heaters, cooling systems and lighting systems. With the use of high-capacity motors, it inevitably involves massive power consumption, which mainly amounts to 35–55 percent of the total power consumption of the factory. Among rubber products manufacturing processes, the rubber material milling process, the extruding process and the rolling process have a relatively higher electricity consumption rate which is more than 50 percent of the total consumption, and the vulcanizing process has 80 percent more or less of the total consumption and it entails all employees to present pragmatic proposals for an energy conservation — an exigency — by being motivated. In a Rubber manufacturing factory, electric power and fuel are the main items to be controlled (UNIDO, 1998).. In reality, the cost of energy is everybody's problem and it is a variable and a controllable cost. Most rubber processors could easily reduce energy costs (without large investments) and increase profits through good energy management practices.

According to scientific taxonomy (classification) of plants for systematic study, under bi-nominal nomenclature (two name system), the rubber tree is botanically known as Havea brasiliensis (Family: Haveacae, Genus: Havea, Species: Brasiliensis) (http://www.kew.org/science-conservation/plants-fungi/hevea-brasiliensis-rubber-tree accessed on 12.09.2013). The Rubber tree originated in Brazil and the South American Rain Forests as an endemic plant. The indigenous Amazon tribes had known the economic uses of this tree for generations Rubber seeds are rich in oil and the trunk in latex. With the invention of motor and immediately the engine automobile industry in the late Nineteenth Century, the demand for natural rubber increased by the year 1905 and there were more than 300,000 ha of rubber grown in both Sri Lanka and Malaysia by that time (http://www.horanaplantations.com/History-of-Rubber.html accessed on 12.09.2013). The history of Sri Lanka's rubber industry began the way back in 1876 with the ceremonious planting of rubber trees in Henerathgoda Gardens in Gampaha as an exotic plant (non-native plant) (http://www.srilankaheritages.com/henarathgoda.html accessed on dated 12.09.2013). It is extensively planted in Sri Lanka as plantation agriculture.

Rubber mills use predominantly diesel, wood and liquefied petroleum gas (LPG). The production of ammonia and chemicals predominantly takes place at the stage of using concentrated latex. In Sri Lanka raw dry rubber is produced and it is used in the production of tyres, tubes, toys, shoes and other different types of productions as raw materials. Some factories produce concentrated latex to make surgical gloves and hospital gloves, condoms, balloons and other rubber products. In the Sri Lankan context, there was no alternative to living with climate change. But such option is essential though its contribution is negligible to global warming and human beings are highly vulnerable to climate change.

Table 1 reflects the energy consumption of the rubber industry. Based on the estimates of Central Bank of Sri Lanka, the industrial sector contributes about 30 percent to the Gross Domestic Product (GDP) and rubber based products contributes about 5 percent (Jayawardena, 2013). Results denote that the industry has consumed a significant amount of energy in terms of the rupee.

Table 1
Type of energy use in rubber product manufacturing.

Industry division	Rubber products (more than 25 persons engaged factory)	Rubber & plastic (less than 25 persons engaged factory)
Fuel & electricity total (Rs.)	4,813,983,284	353,138,433
Electricity (Rs.)	2,614,359,207	260,424,778
Furnace (Rs.)	896,085,259	15,619,075
Diesel (Rs.)	314,977,700	24,944,532
Kerosene (Rs.)	52,972,080	737,867
Petrol (Rs.)	47,850,814	4,534,100
L.P.G. (Rs.)	20,530,227	37,888,271
Charcoal (Rs.)	208,096,259	14,600
Firewood (Rs.)	452,702,089	3,661,274
Water (Rs.)	190,168,153	3,536,752
Other fuel (Rs.)	16,241,497	1,777,183

Source: Annual Industry Survey 2011.

1.1. Clean development mechanism in Sri Lanka

Many developed countries have adopted cleaner production mechanisms as a strategy in their manufacturing processes than their counterparts in the developing countries. Cleaner Production (CP) is useful in addressing pollution during industrial production. CP is not against industrial development and expansion, but emphasizes that development and expansion be sustainable. Mitigation measures in general provide better results than in other types of initiatives. Application of cleaner production results in gainful competitive advantage through managing energy efficiency, waste reduction, increased recycling, increased quality, better environmental credentials, greater customer satisfaction, new business opportunities, achieving local community support, attaining increased staff commitment, positive pressure group relations, improved media coverage or a combination of all these benefits. This will result in greener production process. Sri Lanka has taken an initiative to take important steps to support the UNFCCC. Those were assented to, at the Kyoto Protocol on the third of September 2002 and also Kyoto Protocol resolved to establish Designated National Authority for the Clean Development Mechanism (CDM) project activities, prepared a national framework policy on CDM, established two national CDM study centres at two leading Universities, and set up a National strategy study on climate change.

1.2. National policy on clean development mechanism in Sri Lanka

The objective of the national policy was to contribute to sustainable development through developing and establishing the institutional, financial, human resources and legislative framework necessary to participate in Clean Development Mechanism (CDM) activities under the Kyoto Protocol while developing a mechanism for trading "Certified Emissions Reductions" (CER) and "Removal Units" (RMU) drawn through CDM activities.

However, while carbon-intensive sectors appear to be pursuing a moral legitimating strategy underpinned by substantive action, the less intensive sectors are relying more heavily on symbolic disclosure. In order to minimize the carbon footprint and by the definition of the CP introduced by the United Nations Environment Programme (UNEP) defined it thus:

> "Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment"
>
> Moreover, Fore and Mbohwa (2010), says, "Cleaner production (CP) is useful in addressing pollution during industrial production."

Apart from CP, one of the scientific methods typically applied is 'Life Cycle Analysis' (LCA) which is used for measuring, reporting and verifying carbon emitted during production. The LCA method (Guinée and Heijungs, 1995) is useful for evaluating CO_2 emission during production process. LCA has been widely applied in carbon footprint accounting in the literature. Anthropogenic GHG emissions to the atmosphere are regarded as the chief contributor to the global warming.

In addition, taking care of the materials, energy, water, waste and emissions makes good business sense. Hence Resource Efficient and Cleaner Production (RECP) is the way to achieve this. Thus RECP covers the application of preventive management strategies that increase the productive use of natural resources, minimize production of waste and emissions and foster safe and responsible production. Furthermore, benefits are imminent in many enterprises, regardless of sector, location or size (NCPC, Sri Lanka – undated).

Ze-hua et al. (2011) stated that, Cleaner Production includes conservation of raw materials and energy, avoiding use of toxic materials, reducing the quantity and toxicity of emissions before leaving producing process. Cleaner Production includes clean producing process and products. It not only tries to achieve non-pollution or less polluting production process, but also tries to lowering the harm to the environment during the usage and scrap disposal of the products. Cleaner Production is reflected in both the cleaning process and clean products, and these to be achieved by process design, product design and internal management. Cleaner Production is the key of ecological project implementation.

Liu et al. (2011) stated that presently, the promotion of cleaner production and acceleration of the ecological construction of the industrial system has been acknowledged worldwide as one of the key technologies to achieve the objectives of the diversion of the ecological system, diversion of the production system and the development of the recycled economy.

1.3. The national policy on cleaner production in Sri Lanka

Batuwitage (2011) stated that, in year 2005, Ministry of Environment developed a National Cleaner Production (CP) Policy. This emphasize in promote and preventive environmental strategies than addition pollution to the process. The Goals of the National CP Policy are (i) Achieve sustainable development in Sri Lanka, (ii) Improve environmental quality throughout Sri Lanka, (iii) Improve eco-efficiency across all sectors of the economy in Sri Lanka, (iv) Alleviate poverty and improve living standards of all Sri Lankans. The national CP policy calls for the development of sectoral policies to sufficiently integrate CP practices in the sectoral development agenda. The Ministry of Industrial Development (MID) also developed the industrial CP policy and the National Cleaner Production Centre (NCPC) was established under the MID as part of the UNIDO/UNEP NCPC network.

1.4. Problem statement

Despite the availability of many methods for minimizing carbon footprint during the production process, implementation of methodology has not yet got established. This has been due to many reasons and still implementation strategies are yet to play a major role. On realizing the above felt need, the research focuses on the theme of problem as "*What are the existing situations of implementation of energy-efficient carbon footprint minimizing strategy in Small and Medium Scale Enterprises, with special reference to the barriers of introduction of such energy-efficient carbon footprint minimizing measures in Small and Medium Scale Enterprises in Sri Lanka?*". In the course of this critical study, it was realized that implementation of strategies should be a collaboration of all the stakeholders since the ultimate beneficiary is the community at large that embodies all the stakeholders. The process of this research is manifestly based on a comprehensive representative sample of the rubber products manufacturing SMEs in Sri Lanka and its current contribution for minimizing emission of carbon footprint through their energy efficiency.

1.5. Objective of the study

The broad objective of this study is to identify existing situations of implementing energy efficiency measures in SMEs in carbon footprint minimizing and identifying barriers and challenges of implementing energy efficiency carbon footprint mitigation measures in SMEs in Sri Lanka. The following objectives guided the research project.

1. To identify factors affecting the measurement of carbon footprint
2. To identify the rubber products manufacturing SMEs attitude towards minimizing carbon footprint
3. To find out major barriers in implementing strategies for minimizing energy-efficient carbon footprint
4. To develop a calculation model for the quantify energy-efficient carbon footprint level for rubber products manufacturing SMEs

1.6. Small and medium scale enterprises

According to Thiruchelvam et al. (2003) and Singh et al. (2010) Small and Medium scale Enterprises (SMEs) play a vital role in the developing economies by contributing to the national economic output generating potential employment and this sector is considered as engine for economic growth and development and though this sector being a major contributor to local economic development, yet there is no international agreement on a definition for the term 'Small and Medium sized Enterprises' (National Strategy for Small & Medium Industries Development in Sri Lanka, 2002; OECD, 2009).

Agan et al. (2013) stated that, climate change and environmental pollution have become a cause of universal concern. Companies, both large and small, are contributing to environmental, pollution by emitting waste in gas, liquid and solid forms. It is widely accepted that, SMEs are responsible for 70 percent of all industrial pollution (Hillary, 1995 cited by Agan et al., 2013). The fact that on average, a manufacturer spends more than 60 percent of its income on materials and services (Krajewski et al., 2010 cited by Agan et al., 2013) confirms that SMEs produce a large and usually polluting share of finished products.

2. Literature review and hypotheses development

2.1. Energy efficiency attributes of SMEs

2.1.1. H_1 – relationship between energy efficiency and carbon footprint reducing measures

Thiruchelvam et al. (2003) point out that, SMEs are still disinclined to adopt energy-efficient and environmentally sound technologies due to their inherent characteristics and resistance to change. Research and Development (R&D) emphasise that dual functions of improving energy efficiency and reducing pollution are mostly neglected, especially in the SME sector. According to Narayanaswamy and Scott (2001) and cited by Thiruchelvam et al. (2003), stated that, SME sector also cannot afford expensive research and development and pay for technology transfers.

Many renewable energy sources such as wind power, solar, hydro, bio-based power are becoming more price competitive against the traditional fossil fuels as the ever changing energy market structure has created new competitive pressure. Shi et al. (2012) point out that, for businesses with high-energy intensity and its energy productivity measure can be a major index for its competitive advantage. Companies selling goods and services that promise customers with improved energy efficiency devices will also increase market share.

Santoyo-Castelazo and Azapagic (2014) stated that, sustainable development of energy systems is becoming increasingly more important for policy and decision makers worldwide. It has been argued that in order to secure energy supply for the future, it is essential to promote a diversification of the energy sector based low-carbon technologies (Greenpeace and EREC, 2008b; IEA and OECD, 2008; cited by Santoyo-Castelazo and Azapagic, 2014). For this reason, the financial support and appropriate energy policies are essential (Santoyo-Castelazo and Azapagic, 2014). Morfeldt et al. (2014) stated that, higher CO_2 reductions can be attained by improved manufacturing processes, which are intrinsically more energy-efficient and/or low in CO_2 emissions.

2.2. Cost of implementation for cleaner manufacturing

2.2.1. H_2 – relationship between cost of implementation and carbon footprint reducing measures

Environmental friendly disbursements are associated with capital expenditure for implementing cleaner production. According to Esty and Winston (2009) and cited by Shi et al. (2012), companies can burden millions of dollars on pollution control equipment which consume managerial time and fines for mismanagement of environmental issues. Instead firms espouse the cause of waste management that will benefit from financial savings in the long run. Thiruchelvam et al. (2003), Gallup and Marcotte (2004), Lee (2009) and cited by Lee et al. (2012) emphasise on the lack of finances and the repercussions thereof in the purchase of inferior or second hand technology, low quality or inefficient equipment and expensive environmental management systems (EMSs) such as ISO 14001, Lee (2009) and cited by Lee et al. (2012) as well as environmental audit programs to better control their vendors to keep current contracts. As a result of the advantage of scale economies for the large industry, the SME sector is forced to audit inferior technology to thwart the effects of end product price.

According to Thiruchelvam et al. (2003), many small and medium-sized companies are too resource-poor to contemplate even on minor changes to their operations or to contemplate even on minor investments in process changes to their operations or owing to the fact that new equipment can be competitive. Visvanathan and Norbu (2006) and Shi et al. (2012) emphasise on recycling and not only it provides economic benefits but also its after-effects. Source reduction coupled with reuse can help reduce waste handling and disposal costs, by avoiding the cost of recycling. This involves the reprocessing of waste into a usable raw material or product and 'thereby enabling' materials to have an extended life in addition to reducing resource consumption and avoiding disposal costs.

However, since industries would only be interested in the use of recycled materials when they cost less than primal materials, the practice of recycling is so market-driven that recycling has become selective. The disposal of those unselected recyclables remains a problem. It is also the case that, the rising costs of primary inputs can create new business opportunities for the developing countries, as much as for the developed countries (UNIDO, 2010).

2.3. Attitude of the owner for cleaner manufacturing

2.3.1. H_3 – relationship between strategy for technical inputs of the owner and carbon footprint reducing measures

Further Thiruchelvam et al. (2003) in their report stated that, owners/managers of SME are usually both less motivated and eager to share or collect such information on "Energy Efficiency and Environmental Sound Technology" (E^3ST), as whom to contact, where to get the required financial and technical help, government policies and initiatives on E^3ST, etc. Many owners of the SMEs have little or no formal education or training and the limitations and maintenance requirements of the E^3ST equipment installed are not well understood. It is a situation which could easily lead to equipment malfunction.

Lee (2009) cited by Lee et al. (2012) emphasise that, systematic green management helps enhancing operational efficiencies.

Therefore awareness of the need for ecologically responsible practices and production is a priority. Peattie (1995) and Welford (2000) and cited by Manaktola and Jauhari (2007) defines Systematic Green Management as the management process responsible for identifying, anticipating and satisfying the requirements of customers and society, in a profitable and sustainable way and further say that "firms adopted waste management that will benefit in the long run". According to Maxwell et al. (1997), Savely et al. (2007) cited by Shi et al. (2012), state that, clear environmental policy to guide their environmental developments which include the guideline; such a policy also demonstrates determination to embrace environmental sustainability. An environmental policy is top management's declaration of its commitment to the environment. This policy presents a unifying vision of environmental concern of the entire company and it serves as the foundation of environmental management.

2.3.2. H_4 – relationship between value of the business and carbon footprint reducing measures

According to UNIDO (2010), by definition of the term 'cleaner production' it means that cleaner production creates value for a company by reducing its operational costs through the elimination of inefficiencies in the use of materials and energy, which in turn happens to have environmental benefits. Harvard Business Green (2008), p. 42 cited by Menzel et al. (2010) categorically states that:

> "Companies were able to gain a competitive advantage and value of the business via combination of benefits. Further owing to their small size, SMEs, may be flexible enough to move quickly to offer 'greener' products in order to appeal to consumers who are increasingly concerned with environmental or social issues"

Regarding such factors as affecting global warming today, environmental involvement in any production process is an issue that confers higher importance due to global warming potential in the present context of warming potential. As Clarke and Clegg (2000) cited by Gunathilaka and Gunawardana (2014) emphasise that, as a result global warming, environmental sustainability has become a major concern among managers and is the focal point of the balance between environment and business need.

Many business organizations are now paying attention to the natural environment. The concepts of "management" and "environmental prevention" have become essential to the business world due to the emergence of new outlook on environmental management (Silva and Medeiros, 2004, cited by Hoque and Clarke, 2013). When we ponder on employment, the "decent" jobs we note are those that help to reduce consumption of energy and raw materials, de-carbonize the economy, protect and restore ecosystems and biodiversity and minimize the production of waste and pollution (ILO, 2011). This will lead to improve the profitability of the organization and reduce the carbon footprint.

SME in close proximity to the large industries would establish a synergetic effect whereby both industries could benefit. Some of the benefits are reduction in operating costs (Warren-Meyer, 2012; Braun, 2010 cited by Kirchoff et al., 2011), especially in materials — water and energy, reduction in pre-treatment and off-site disposal costs, reduction in environmental liability and improvement in public image (UNEP, 1997). This is stated as management of a supply chain (European Commission, 2010 cited by Jensen, 2012) that can manufacture and deliver products in a manner that is both cost efficient and less impactful to the environment and it is recognized as a critical component of creating truly green products (Warren-Meyer, 2012 cited by Kirchoff et al., 2011).

Nelson et al. (2011) stated that, accurate and comparable emissions data are critical in assessing the financial impacts on industries and companies due to the introduction of an emission trading scheme or carbon tax. It is imperative to appraise how policies designed to price GHG emissions as a negative externality should be considered in any analysis of individual business profitability.

2.3.3. H_5 – relationship between attitude of the owner and carbon footprint reducing measures

According to Thiruchelvam et al. (2003) owning to a lack of awareness of the impact of carbon footprint the graving of the problem is enhanced among the owners and managers has and there is an increase in pollution from fuel consumption in Sri Lanka, though fuel wood use is important in the industries. Gallup and Marcotte (2004) emphasise that, 'Train-the-trainer' courses in many countries help develop local capacity to provide training in pollution prevention and their countries were producing the wrong product mix with inefficient machinery.

Thiruchelvam et al. (2003) emphasise that to more often, a lack of knowledge and 'correct' information by SMEs deter the effectiveness of the conservation of eco-system programmes. Demonstration projects, training, information education campaign, information clearing house for technology transfers, public awareness campaigns, reporting of success stories, publications in media, presentation of awards, conducting workshops and seminars are some of the methods adopted by many countries and institutions to disseminate knowledge.

2.3.4. H_6 – relationship between strategy of the owner and carbon footprint reducing measures

Environmental management has become a strategic business issue (Corbett and Cutler, 2000, cited by Hoque and Clarke, 2013). Environmental management as a competitive priority for manufacturing by using the 3R principles — reduce, recycle and reuse — is in vague (Jabbour et al., 2012, cited by Hoque and Clarke, 2013). There are many companies to create innovate solutions that reconcile prosperity with environmental protection. Pollution prevention has become an important issue for manufacturers (Jabbour et al., 2012, cited by Hoque and Clarke, 2013).

Pollution prevention refers to any in-plant practice of industrial plants, which eliminates the amount of pollutants that would have been released to the natural environment at the source (Ngwakwe, 2011; Asian Development Bank, 1994, cited by Hoque and Clarke, 2013). Pollution prevention strategies are receiving significant attention in industrial plants all over the world, complementing end-of-pipe pollution control and management strategies (Hossain et al., 2008, cited by Hoque and Clarke, 2013). From sustainable perspective, any solution should encourage pollution prevention at source (Kathuria, 2009, cited by Hoque and Clarke, 2013). Environmental aspects are associated with firms' raw material procurement, manufacturing process, energy usage, product development, marketing, disposal and waste management (Benerjee, 2001 cited by Hoque and Clarke, 2013).

2.4. Demand from stakeholders for cleaner manufactured products

2.4.1. H_7 – relationship between demand from stakeholders and carbon footprint reducing measures

In order to enable consumers to make informed choices, it is necessary to efficiently communicate to them about climate impact caused. Röös and Tjärnemo (2011) point out that, marketing communication is the most possible way to deliver the message. EC

(2007) and as cited by Röös and Tjärnemo (2011) it indicates that, surprisingly, climate change aspects are not yet incorporated into marketing communication schemes or focused on other environmental targets such as a non-toxic environment, i.e. — habitat of a rich diversity of plant and animal life, and the use of nutrients in a closed cycle.

According to Manaktola and Jauhari (2007) traditionally, the concept of "green marketing" seems to be the one associated with hype and exaggerated claims about a product's environmental impact instead of the positive information related to the products. Hilary (2000) as cited by Loucks et al. (2010) emphasise that, SMEs are "largely ignorant" about their environmental impact and environmental regulation and Small businesses tend to face less pressure from external stakeholders.

According to Fisher et al. (1997), Jüttner et al. (2007) and cited by Kirchoff et al. (2011) regarding the ever-growing awareness of climate change by the public, they are more interested in environmental information and companies and organisations are expected to report about their environmental impact. Also firm's marketing and supply chain functions are managed in such a way that their coordination ensures customers receive what they are promised. Baranzini et al. (2000) point out that, market forces will spontaneously work in a cost-effective way to reduce the quantity of emissions. Henriques and Sadorsky (1999) cited by Kirchoff et al. (2011) point out that, managers perceive stakeholder pressure to act in an environmentally responsible manner as critical to help satisfy stakeholder demands and increase stakeholder satisfaction. According to Kassarjian (1971), Freeman (1989), Klein (1990), McCloskey (1990), Kapelianis et al. (1996), Laroche et al. (2001) cited by Manaktola and Jauhari (2007) the emphasis is such that, for consumers who are more receptive to environmental products purchase by choice and there may be a segment that is willing to pay more for the environmental benefit.

Public perception and acceptability is the key to the implementation of any energy technology, be it fossil fuels with or without carbon capture and storage (CCS), renewable or nuclear power (Gallego-Carrera and Mack, 2010; Onat and Bayar, 2010 cited by Santoyo-Castelazo and Azapagic, 2014).

2.5. Role of the government for cleaner manufacturing

2.5.1. H_8 — relationship between government strategy and carbon footprint reducing measures

Thiruchelvam et al. (2003) point out that, the industry and government agencies should work together to reduce pollution. In many countries, when the government departments do not act swiftly to curtail pollution, legal authorities intervene to find a solution or force the government to act. According to Brenton et al. (2009) it is important that an agreed framework for calculating a carbon footprint exist and there is the potential to draw the boundary in different ways. According to Tuttle and Heap (2008) tax policy can be an effective instrument to encourage green productivity and according to Shi et al. (2012) such government policies, as the EU Integrated Product Policies (IPP), drive green consumerism through setting of guidelines and regulatory requirements in pushing business to produce environmentally-friendly products and facilitating coordination with consumer groups, are very important.

Further Thiruchelvam et al. (2003) emphasise that, though energy policies have been declared by Sri Lanka, it is still in the process of policy implementation stage. The existing policies are however, merely targets of high-energy-intensive large-scale industries and are not specific to SMEs.

2.5.2. H_9 — relationship between government solution and carbon footprint reducing measures

Governments are encouraged to play a major role to create a market that recognizes renewable energy for industrial purposes and industries reciprocating effectively using the renewable materials primarily as a biomass to nurture sustainability. Introduction of the concept of a Locally Integrated Energy System (LIES) for the distribution of heat requiring the small-scale industrial plants and the households, businesses, social premises, and this effort demonstrates integration of renewable energy practices using the total site targeting methodology as remedial measures (Perry et al., 2008).

According to Visvanathan and Norbu (2006), Production and consumption rates are rising and government awareness is still low toward issues on waste. The world's government, civil society leaders and business people agree on the emission reduction targets are necessary to mitigate the effects of global climate change, but the questions still remain unsolved. Wyk (2010) pointed out that, education and motivation fail, for instance, when people are unwilling to cooperate in the conservation effort, and where other incentives are ineffective, regulation may be the best way to exert pressure and compel people to protect biodiversity.

As cited in the report prepared by Gilbert et al. (2014), the European Commission has renewable commitments (2009) and the UK Government has established carbon budgets and set targets to 2050 to ensure that all sectors mitigate carbon emission level at a rate that is compatible with avoidance of this 20 °C temperature rise.

2.6. Fishbone model

Phillips (2013) stated that, in the 1950s, Japanese Professor Kaurou Ishikawa was the first person to describe the cause of a problem using a visual diagram, commonly known as the fishbone analysis diagram, named for its resemblance to a fish backbone and ribs. It has since become a key diagnostic tool for analysing and illustrating problems within root-cause analysis (Galley, 2012 cited by Phillips, 2013). Further Phillips (2013) stated that, Fishbone Analysis begins with a problem and the fishbone provides a template to separate and categorise the causes. This method allows problems to be analysed and, if it is used with colleagues it gives everybody an insight into the problem, so solutions can be developed collaboratively.

2.7. Calculation model

Jawjit et al. (2010) stated that, primary rubber products are quantified as a function of activities and emission factors which show in the following equation: Aggregate different energy carries into one single score as follows:

$$E_{x,i,j} = \sum \left(A_{ij} x \mathrm{EF}_{x,I,j} x \mathrm{GWP}_x\right)$$

where $E_{x,i,j}$ are emissions of greenhouse gas x (index for type of greenhouse gases: CO_2, CH_4, N_2O) associated with activities i (index for type of activities) in the production of product j (index for type of products) (kg CO_2-eq/ton product). A_{ij} is the level of activity i in the production of product j, and $E_{x,i,j}$ is the emission factor for greenhouse gas x due to activity i in production of product j. and GWP_x is the global warming potential of greenhouse gas x.

'Impact Categories for Natural Resources and Land Use' (1997) Centre of Environmental Science (CML), Leiden in their report stated that, the characterization stage of life impact assessment is defined as the step in which the environmental interventions are translated in terms of contributions to a selected number of environmental impact categories. The formula created is given as follows:

$$\text{Impact Score}_{\text{category}} = \sum \text{Equivalency Factor}_{\text{category,type}} \times \text{Intervention Amount}_{\text{Type}}$$

3. Research methodology

The research was conducted in three phases. Thus research methodology is discussed in three phases. A semi-structured questionnaire is used to gather data from industrialists in the first phase. Face to face interviews were conducted to collect desk information from industry experts in the second phase. After having detailed discussions with industry management the researcher derived a flow chart developed from data collection sheet under energy consumption. This data was used for the detailed analysis of CO_2 emission levels in phase three. Secondary data were collected from available relevant open sources. Data collection was guided by three principles of data collection: using multiple sources, creating a case study database and maintaining chain of evidence (Yin, 1989 as cited by Tellis (1997) in Application of a Case Study Methodology).

3.1. Population and sample

The population of 408 (Colombo – 310, Gampaha – 62 and Kalutara – 36) industries registered under the Ministry of Industry and Commerce of Sri Lanka coverage was selected. The data was collected from the Western Province of Sri Lanka. Table 2 reveals the sample size of each area.

3.2. Data collection

This study mainly employed a qualitative and a quantitative approach to gather information using stratified random sampling method under the probability sampling method to gather industrialist perspectives using a Likert Scale (5 – Strongly Agreed, 1 – Strongly Disagreed). Unstructured questionnaire used to gather industry experts opinion. Data collected based on the data sheet developed for the detailed analysis of CO_2 emission levels.

3.2.1. Primary data collection

Desk information from 25 industry experts was collected prior to sorting data from the field. Focused discussions were held with the Chief Executive Officer of National Cleaner Production Center (NCPC), SME consultant from Federation of Chamber of Commerce and Industries of Sri Lanka, Deputy Director-Ministry of Industry and Commerce, officials from the Plastic and Rubber Institute, the Rubber Research Institute of Sri Lanka and other specialists and professionals in the field. Expertise obtained has given an inspirational encouragement to the research project which took two months to gather this data from January 2013.

Table 2
Frequency of the area analysis.

District	Industrialists	Case study	Industry expert
Colombo	76	1	25
Gampaha	15	1	
Kalutara	9	1	
Total	100	3	25

Source: Constructed by author.

Responses to one hundred questionnaires were collected from rubber product manufacturing SMEs registered under the Ministry of Industry and Commerce, Sri Lanka from January 15, 2013 to May15, 2013. Prior to the actual data gathering a pre-test on the questionnaire was carried out in three locations stated above in collecting data. Since the researcher identified errors in the questionnaire, the same was re-designed and data collected accordingly. Before the actual surveys were conducted, proper contacts were made with respective authorities. The researcher participated in industry progress review meetings held in the Ministry of Industry and Commerce and interacted with SME groups in the Industrial Zones of Sri Lanka. At seminars, workshops and gatherings all participants actively engaged in experiencing the set-up while at the same time observing and discussing with industry participants about whatever is happening.

Generally the business owner was the priority consideration in the selection of the factories that responded to the questionnaire for data collection. When the factory owner was not available, his/her successor or the technical expert or most senior person became the second choice for the data collection. In the case of non-response to questionnaire during the data collection, subsequent call back was made to each such factory owner at different times to meet them to collect their information. The objective of the research was to give a valid introduction to the interviewee and ethical clearance statements were obtained. Thereafter data collection started. Also certain data were collected ad-hoc while industrialists were having their monthly meetings and forums, and meetings were held at the Ministry of Industry and Commerce.

To identify the carbon emission level, researcher measured the data gathered physically from selected three rubber band manufacturing factories during the month of July 2013 and data recorded while the manufacturing process was in progress.

3.2.2. Secondary data collection

Secondary data that was collected from literature such as text books, journals, and reports, because some of the information may not be accessible in libraries. Therefore an archive-study of reports had to be conducted at industry level and at the national archives in the industry. The whole process took a considerable period of time.

4. Data analysis and results

4.1. Primary data analysis

Unit of analysis was industrialists. Before entering and analysing the data, all completed questionnaires were screened with the aim of detecting lapses and filling gaps. These findings are reflected on the data presentation and analysis. Data were collected from industrialists through questionnaire — illustrated in both tabular and graphical forms.

4.2. Operationalization of variables

4.2.1. Validation of measurement properties

Measurement Properties of the instrument developed for measuring the carbon footprint reduction through analysis of rubber production in Small and Medium Scale Enterprises in Sri Lanka were assessed through testing for reliability.

4.2.2. Factor analysis and reliability test

Factor analysis and reliability testing reveal Table 3. Factor analysis identifies the pattern of underlying variables of correlations with the set of observations of variable. This is important to identify a small number reducing data. Also this is used to screen the variables for subsequent analysis to generate hypothesis.

Table 3
Test statistics.

Factor	KMO measure of sampling adequacy.	Bartlett's test of sphericity			Cronbach's alpha	No of items
		Approx. chi-square	df	Sig.		
Energy efficiency	0.760	147.089	15	0.000	0.794	05
Cost of implementation	0.773	136.396	10	0.000	0.790	05
Strategy for technical inputs	0.723	226.586	15	0.000	0.829	06
Value of business	0.831	461.349	15	0.000	0.896	06
Attitude of the owner	0.756	961.596	45	0.000	0.953	10
Strategy of the owner	0.767	138.437	10	0.000	0.933	10
Demand from stakeholders	0.723	226.586	15	0.000	0.829	06
Government solution	0.772	171.177	10	0.000	0.811	05
Government strategy	0.801	289.433	15	0.000	0.847	06

Source: Compiled by author.

Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy test results revealed that explained total variance explained that tested for nine factors are containing more than 0.7. It revealed that, the factors carry one direction supporting to the main objective of the study.

As the data for this study were collected using Likert scaled responses, it was deemed necessary to test for reliability. Thus, Cronbach's Alpha was calculated for each of the dimensions of barriers and challenges in implementing of energy-efficient minimizing measures of carbon footprint in small and medium scale enterprises (SME) in Sri Lanka to ensure the internal consistency of the instruments. The results are Cronbach's Alpha greater than 0.7 which indicates satisfactory internal consistency and reliability (Malhotra, 2005).

4.2.3. Normality test

The tests of normality overlay a normal curve on actual data, to assess the fit. A significant level of the test equal to zero means the fit is poor. Therefore for all groups, the test of significant level is zero revealing that, they fit the normal distribution curve poorly.

Table 4 reveals normality test results. Kolmogorov–Smirnov test does not take into consideration assessing the normality of findings as it is used for more than 2000 sample size calculations. Therefore the applicable test is Shapiro–Wilk test. This result shows that the significance level (p-value) is less than 0.05, which reveals the result is not normally distributed. Therefore, it is recommended that non-parametric test be applied for this analysis. Table 5 reveals the descriptive statistic values against each factor.

Table 4
Normality statistics.

Factor	Kolmogorov–Smirnov[a]			Shapiro–Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Energy efficiency	0.214	100	0.000	0.896	100	0.000
Cost of implementation	0.247	100	0.000	0.888	100	0.000
Strategy for technical inputs	0.182	100	0.000	0.859	100	0.000
Value of business	0.280	100	0.000	0.835	100	0.000
Attitude of the owner	0.308	100	0.000	0.808	100	0.000
Strategy of the owner	0.206	100	0.000	0.899	100	0.000
Demand from stakeholders	0.182	100	0.000	0.859	100	0.000
Government solution	0.252	100	0.000	0.885	100	0.000
Government strategy	0.261	100	0.000	0.870	100	0.000

[a] Lilliefors significance correction.
Source: Compiled by author.

4.3. Identification of factors affecting the measurement of carbon footprint

Several researchers have taken several steps to develop systems to minimize global warming potentials through minimizing carbon footprint effect. Different institutions have taken steps to make the human being aware of the hard 'goings on' takes effect on the earth due to varied levels of carbon footprint. Different countries have taken strong measures such as taxing and imposing penalty for emitters. In some instances, the export and import departments of countries have imposed certain measurements to indicate carbon footprint levels of manufacturing processes. This has shown at global level that several efforts have been made to mitigate carbon footprint levels for a better future. Factors found out were energy efficiency, cost of implementation, strategy for technical inputs, value of business, attitude of the owner, strategy of the owner, demand from stakeholders, government solution and government strategy to mitigate carbon footprint at a large scale.

4.3.1. Desk information and responses from experts

The first emphasis given was lack of active policy level framework in mitigating carbon footprint by industries. The role of government, academics, researchers and policy makers are not yet taken into consideration the need of implementing the carbon footprint reduction programs into the industries. The focus was to implement a national policy framework which could play a bigger role when the entrepreneurs are either not aware of or negligent of carbon footprint mitigation measures. The suggestion given was the need of introduction and recognition of the low carbon emitters by which appropriate subsidies are put to utility for reduction of carbon emission. Issues at the institutional level are increasing awareness and elaborating qualified professionals who are required to take the lead roles. Also SMEs spend a lot of money on sophisticated machinery to improve their production. But the proper introduction of manufacturing process through CP model will lead to mitigating energy-efficient carbon footprint. The other issue highlighted was that a smaller number of carbon consultants are available in the market. As a result, the existing consultants have to serve both in the public and the private sector establishments. Also there is a lack of civil society organizations to voice criticism on these issues. The collective action including private sector, government and civil society will result in mitigating carbon footprint minimization effort successfully. They collectively suggested that, imposing tax is not a solution, but at policy and regulatory levels and imposing stringent measures to control will provide a solution. Another important component was making the attitudinal change of the people regarding this issue. Then the mitigation measures will work and concrete results will get delivered. The Industries should seriously consider local supply chain processes and should be happy with the implementation. Presumably, Sri Lanka does not move with the market and its requirements.

Development of a social image in the production mechanism practised presently will increase the public purchasing behaviour. Regular improvement of the SME knowledge, regular maintenance of machinery, development of skills of labour on impact of carbon footprint in the future and mitigation measures, introduction of low carbon technology and display of aggressive marketing strategies on products will support improvement of the social image and thereby increase profits. There is no proper screening/verification process for carbon emitters and level by any authority. In Sri Lanka another main issue is the absence of proper network among institutions to discuss and implement mitigation measures. This is mainly due to inadequately of government support in the role of a change agent. There were suggestions that, lack of proper database of industries within all the responsible institutions which should be

Table 5
Descriptive statistics.

Factor	N	Mean	Std. deviation	Skewness		Kurtosis	
	Statistics	Statistics	Statistics	Statistics	Std. error	Statistics	Std. error
Energy efficiency	100	4.320	0.48742	0.047	0.241	1.148	0.478
Cost of implementation	100	4.298	0.49359	0.064	0.241	1.131	0.478
Strategy for technical inputs	100	4.370	0.35421	0.530	0.241	1.044	0.478
Value of business	100	4.350	0.47467	0.24	0.241	1.353	0.478
Attitude of the owner	100	4.374	0.44803	0.299	0.241	1.593	0.478
Strategy of the owner	100	4.322	0.48650	0.037	0.241	1.136	0.478
Demand from stakeholders	100	4.370	0.35421	0.530	0.241	1.044	0.478
Government solution	100	4.312	0.48101	0.076	0.241	1.108	0.478
Government strategy	100	4.313	0.48390	0.172	0.241	1.313	0.478
Total	100						

Source: Compiled by author.

highly equipped with all the information of factories including their products and emission rates. In the promotion strategy focussing should be on expenditure incurred on energy for production.

4.3.2. Responses from industrialists

Identifying the possibility to set-off carbon emission against the rubber estates should be implemented. There are difficulties in relocation of factories with the investments already made and support from government for guidance and other facilities for both low cost and no costs projects. As industrialists, their effort provides maximum support to the country's economy and SME is the cornerstone in this point of view. The cost of energy and application of CP is important. But it is difficult to bear the costs and it takes longer time to absorb the system among SMEs. In their operation SMEs always run into debt, but such additional burden is not taken into account by industrialists. Also, it is difficult to hire highly qualified personnel for these posts due to massive package cost in employment. As a result, SMEs look for only knowledgeable technical staff. Also CP programs should incorporate employee awareness programs to continue the process. Another discernible issue in this critical study is that industrialists are not aware of the role of the NCPC. NCPC should promote case studies especially on energy reduction that will be helpful after using this mechanism. There is a lack of effective marketing in case studies and SMEs themselves lack utilizing aggressive strategies of marketing in their operation. Also the proper marketing strategies for carbon reduction programs are important. This is totally lacking in Sri Lanka. Industrialists prefer purchase of recycled materials, but the availability is very insignificant. Also they are doubtful about product quality as well as of lesser use of recycled materials. Endorsing institutions as green product manufacturers is important. Sometimes, eco-friendly built environment cannot be delineated as a factory to suit the pattern of the production process, security and the construction costs. Therefore, introduction of new methods/designs are important in the context of minimizing carbon emission. Also it must be emphasized that, for the manufacturing process, a building designed as a onetime event instead of having several steps. Relevant industries must sit together to take initiatives in this regard. Also it is important to initiate regular mediation by environmental authority to regularize industrial audits; instead of waiting till the problem being reported by another party. Attitude change is important in the first instance by all in the society. This will provide solutions to all the questions. In this study employers disclosed that, we were trying to enhance the knowledge of our employees, but it is difficult. There are many reasons. Sometimes, they feel the institution is trying to get an advantage of 'using' them. Therefore, it is important that the government also launches initiatives to raise awareness among the common people. Then the institutions can take the lead to do the rest. Government can impose taxes, if there are no solutions, but it should not be the last resort.

4.4. Identification of SME carbon emission attitudes and minimizing carbon emission

4.4.1. Hypothesis testing and statistical data analysis: p-value

One of the common types of statistical inferences is hypothesis testing. Statistical data analysis is a mathematical principle which is used to ascertain whether the sample results match the hypothesis developed for population. When a *p*-value (probability value) is used to decide whether the conviction to reject the null hypothesis in statistical hypothesis testing is explicable, the research concludes those hypotheses are supported by the data. In hypothesis testing *p*-value can be used as a numerical measure of statistical significance. If the *p*-value is less than 0.05 ($p < 0.05$), analysis finding concludes that alternative hypothesis is not rejected. If *p* value is greater than the significant level analysis, it concludes that the results are statistically significant.

4.4.2. Kruskal Wallis test

Table 6 shows the distribution of responses to each question raised in Likert scale questions. The median value distributed from 4.000 to 4.3000. Test results reveal that, *p*-value is less than 0.05 ($p < 0.05$) which concludes that, alternative hypotheses declared are not rejected.

4.4.3. Application of fishbone theory

A cause and effect chart like the fishbone analysis, provides a tool to identify all the possible causes of a problem not just the obvious ones. It seeks to locate the "root" cause of the problem from a systematized perspective rather than through personal views. Diagram 1 reveals the root-cause of carbon footprint minimization

Table 6
Test statistics.[a,b]

Factor	Chi-square	df	Asymp. sig.	Median value
Energy efficiency	16.443	2	0.000	4.200
Cost of implementation	30.765	2	0.000	4.000
Strategy for technical inputs	12.073	2	0.000	4.000
Value of business	28.501	2	0.000	4.000
Attitude of the owner	25.204	2	0.000	4.300
Strategy of the owner	16.610	2	0.000	4.000
Demand from stakeholders	12.073	2	0.000	4.300
Government solution	29.346	2	0.000	4.100
Government strategy	30.774	2	0.000	4.100

[a] Kruskal Wallis test.
[b] Grouping variable: average of variables.
Source: Constructed by author.

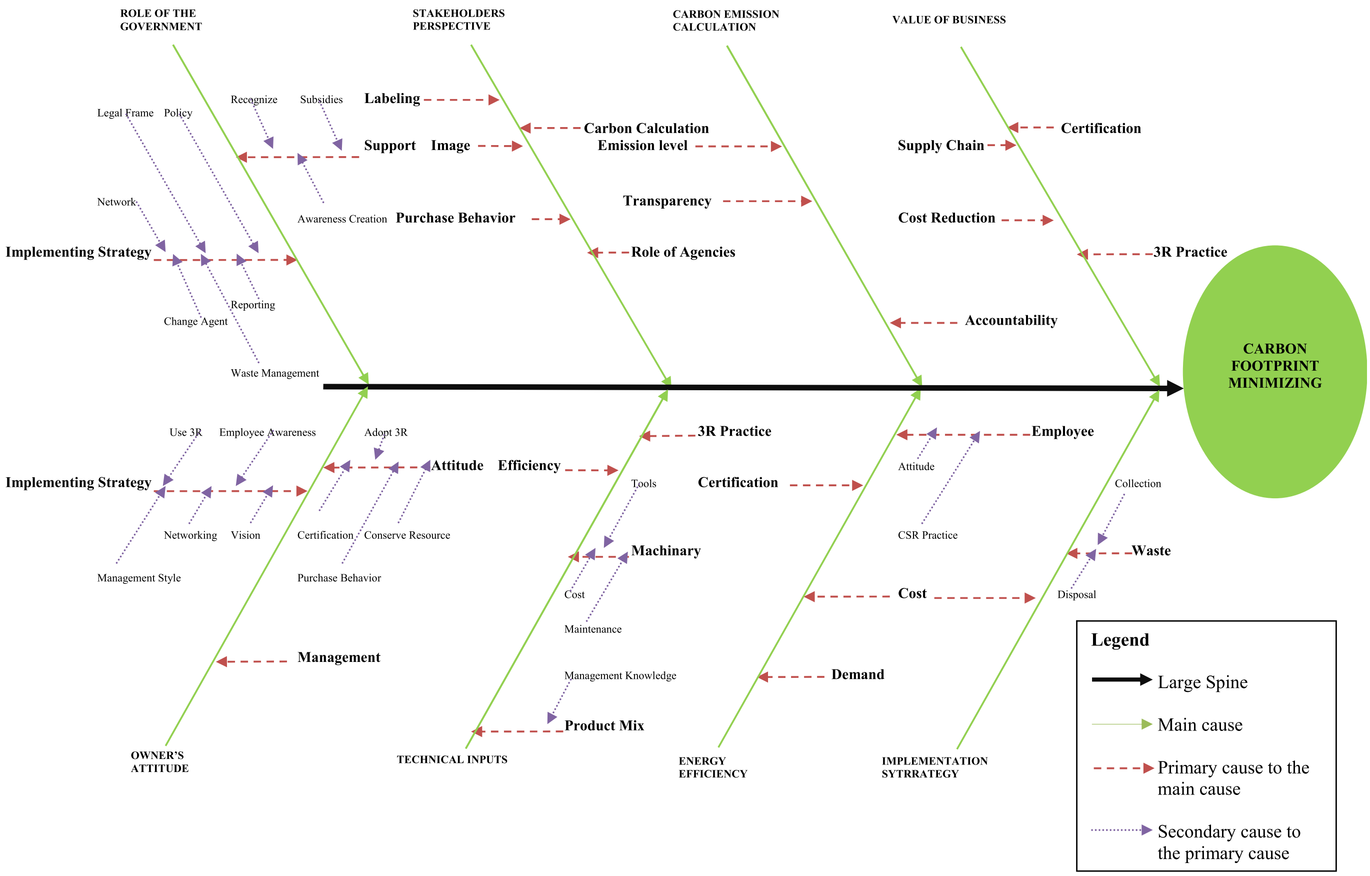


Diagram 1. Fishbone model.
Source: Compiled by author.

measures. The legend of the fishbone diagram — It reveals the effect in eclipse head at the right side linked through large horizontal spine from left to right pointing to the effect — The factors are reflected as main causes connected diagonally to the spine which link the effect. Arrows going from left to right and right to left indicate the primary causes to the factors/main cause. Arrows that run vertically from top to bottom and bottom to top which connect primary causes reflect the reasons for secondary causes. These are illustrated in black, green, red and purple colours (in the web version) respectively. Considering the factors highlighted in the fishbone model, it was observed that, government involvement dividing into two components as implementing strategy and support. Under the strategy component, with inclusion of developing legal framework, implementing a policy, networking with the private sector and other stakeholders, introducing waste management, acting as a change agent and proper reporting mechanism are highlighted. Under the support component, creating awareness of industrialists and citizens, recognizing low carbon emitters and providing subsidies are highlighted.

Stakeholders' requirements were proper labelling, building an image of the product as low carbon emitter, changing purchase behaviour, common method of calculation of carbon emission and role of working groups or agencies to reduce carbon footprint are highlighted. Calculation model revealed its effectiveness of emitters, their liability and display of emission level. Value of the business using green supply chain process, certification as green manufacturer, cost reduction using cleaner production mechanism, using 3R practices to increase the profitability are accentuated. When considering the owner's, requirement it was divided into three main components. Under the strategy using 3R mechanism, creating employee awareness, being efficient in management style, having a corporate vision and networking with stakeholders are accentuated. Under the attitude towards minimizing, adopting 3R mechanism, obtaining ISO certifications and other agencies monitoring low carbon emitting, conserving resources while using during manufacture process, and using green supply chain mechanism are accentuated. Also, managing the entire process efficiently to achieve tangible results are highlighted. Under technicality, ensuring efficiency of machinery, using 3R practices, having the proper production mix by the management are featured. Under machinery, availability of tools, regular maintenance and affordability are featured on.

Under energy, the alternative to regular demand or use of clean energy, proper endorsement as low carbon energy user certification, cost control towards energy use, employee awareness to minimize energy consumption, changing employee attitude towards carbon footprint and implementing corporate social responsibility (CSR) to make employee awareness as well as the energy companies are emphasized. Under implementation, high cost of implement systems, high waste collection and disposal systems are highlighted.

4.5. Ascertaining major barriers implementing strategy of minimizing of carbon footprint

In order to ascertain priority order of major barriers of energy-efficient carbon footprint minimizing were analysed through content analysis of twenty five professionals from one university

Table 7
Content analysis of Institutions and Individuals that responded.

Type of issue	Type of professional respondent												
	Respondent's decision	University academic	SME consultant	Engineers	Lawyers	NCPC	Ministry of industry and commerce	Business chambers	Industrialists	Plastic and rubber institute	Rubber research institute	Total respondents	Rank order
	Nos	1	4	2	1	1	2	2	10	1	1	25	
Need a national policy	Yes	1	4	2	1	1	2	2	10	1	1	25	1
	No	0	0	0	0	0	0	0	0	0	0	0	
Awareness on energy efficiency	Yes	1	4	2	1	1	2	2	8	1	1	23	2
	No	0	0	0	0	0	0	0	2	0	0	2	
Tri-partite agreement required	Yes	1	4	2	1	1	2	2	6	1	1	21	3
	No	0	0	0	0	0	0	0	4	0	0	4	
Awareness on role of the NCPC	Yes	1	4	2	1	1	2	2	5	1	1	20	4
	No	0	0	0	0	0	0	0	5	0	0	5	
Attitude of the owner	Yes	1	2	2	1	0	2	2	7	1	1	19	5
	No	0	2	0	0	1	0	0	3	0	0	6	
Awareness programs on carbon footprint minimizing	Yes	1	4	2	1	1	2	2	3	1	1	18	6
	No	0	0	0	0	0	0	0	7	0	0	7	
Implementation cost of carbon footprint reduction measure are high	Yes	1	0	0	1	1	2	2	10	0	0	17	7
	No	0	4	2	0	0	0	0	0	1	1	8	
Less carbon consultants in the market	Yes	1	0	0	1	1	2	2	7	0	0	14	8
	No	0	4	2	0	0	0	0	3	1	1	11	
No carbon trading mechanism in the market	Yes	1	0	0	1	1	2	2	5	0	0	12	9
	No	0	4	2	0	0	0	0	5	1	1	13	
Value of the business should reduce for carbon emitters	Yes	1	0	0	1	0	2	2	5	0	0	11	10
	No	0	4	2	0	1	0	0	5	1	1	14	

Source: Compiled by author.

academic, four SME consultants, two engineers, one lawyer, one NCPC official, two Ministry of Industry and Commerce officials, two business chamber officials, ten industrialists, one Plastic and Rubber Institute official and one Rubber Research institute official. Data gathered in the form of "yes = 1", "no = 0" and rank order of one to ten.

In the content analysis; Table 7 reveals the rank order of the ten captions under which this research was conducted ranging from one to ten. These demonstrate the need of an active national policy, awareness on energy efficiency, tri-partite agreement requirement, awareness on role of the NCPC, attitude of the owner, awareness programs on carbon footprint minimizing, reduction in high cost of implementation cost of carbon footprint, less carbon consultants in the market, absence of carbon trading mechanism in the market and the reduction of the value of the business of carbon emitters.

Based on the rank order of professionals' opinion, one to five were considered as major barriers in implementing energy-efficient carbon footprint mitigating measures which incorporate a national policy, awareness on energy efficiency, tri-partite agreement required, awareness on role of the NCPC considered.

4.6. *Developing a carbon emission calculation model*

4.6.1. *Measurement of existing energy usage level*

Data collected in detail is from production process (milling). There was the sameness prevailing in all the selected factories regarding the number of workers, production capacity, machinery types and working patterns. During site visits, discussions and interviews de-facto/valid/bona-fide, vital data were collected and analysed with the owners of the mills and technicians. It was observed that in the selected factories they were using Ceylon Electricity Board (CEB) electricity and furnace oil for energy generating purposes in the rubber band manufacturing process. The analysis was effected beginning from raw rubber or master batches to dispatching (gate to gate) during the research. Table 8 reveals the detail data collected.

Table 9 reveals usage levels of electricity and furnace oil for the production of rubber band per month by the three factories A, B and C respectively. According to UNFCCC, an emission factor is defined as the average emission rate of a given GHG for a given source, relative to units of activity (www.unfccc.int accessed on 16.08.2014).

Table 9
Usage level of energy and rubber band production.

Particulars	Factory A	Factory B	Factory C
Electricity: total kWh consumption at factory, per month (kWh)	18,451.45	29,354.98	18,531.75
Furnace oil: furnace oil for rubber band lines, per month (l)	7000.00	9500.00	7250.00
Monthly rubber band production (ton)	25.80	28.00	25.00

Source: Compiled by author.

Table 10
Rubber band productivity ratio.

Particulars	Factory A	Factory B	Factory C
Daily kW usage	738.06	978.50	741.27
No of days worked	25.00	30.00	25.00
Monthly usage, kW	18,451.45	29,354.98	18,531.75
Value of one kW/H (Rs)	15.56	15.56	15.56
Total cost of kW/H (Rs)	287,104.56	456,763.52	288,354.03
Monthly rubber band output (ton)	25.80	28.00	25.00
Value per rubber band ton (Rs)	750,000.00	755,000.00	740,000.00
Total value of output (Rs)	19,350,000.00	21,140,000.00	18,500,000.00
Productivity ratio per kW/H per month	67.40	46.28	64.16

Source: Compiled by author.

Table 10 and Graph 1 indicate the daily electricity usage levels, number of days worked, monthly electricity usage levels (daily electricity usage × number of days worked), value of one kW/H (selling price of electricity 1 kW/H), total cost of electricity usage (monthly electricity usage × value of one kW/H), monthly rubber band output in tons, value per rubber band ton and total value of the output (monthly rubber band output × value per rubber band ton).

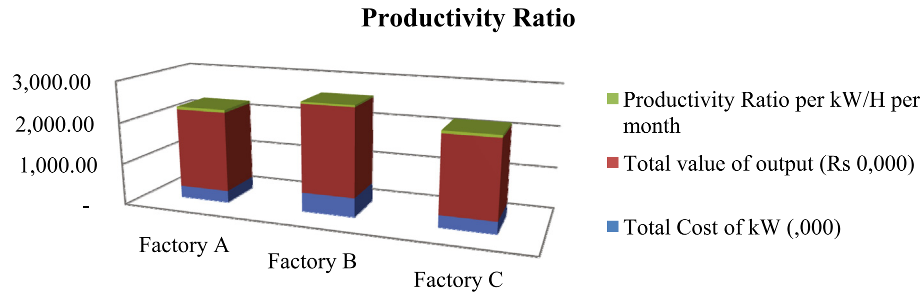
4.6.2. *Emission level against electricity usage*

Data compiled from factory A, B and C, Table 11 shows the total electricity consumption per month and the emission level, CO_2

Table 8
Energy usage for rubber band manufacturing.

Machine information		Factory A				Factory B				Factory C			
		July 2013, 7.00 am–4.00 pm shift				July 2013, 7.00 am–6.00 pm shift				July 2013, 7.00 am–4.00 pm shift			
No	Machine	kW	hrs/day	kWh/day	Effective load	kW	hrs/day	kWh/day	Effective load	kW	hrs/day	kWh/day	Effective load
1	Bale cutter	1.50	1.00	1.50	0.60	1.50	1.50	2.25	0.97	1.55	1.00	1.55	0.62
2	Two rolls mill 1	56.00	6.00	336.00	134.40	55.95	7.00	391.65	168.41	55.00	6.00	330.00	132.00
4	Boiler burner	7.50	5.00	37.50	15.00	7.50	5.50	41.25	17.74	7.50	5.00	37.50	15.00
5	Pre-heating mill	45.00	6.00	270.00	108.00	44.76	7.50	335.70	144.35	46.00	6.00	276.00	110.40
6	Strainer 1	22.50	6.00	135.00	54.00	22.38	7.50	167.85	72.18	22.50	6.00	135.00	54.00
7	Strainer 2	22.50	6.00	135.00	54.00	22.38	7.50	167.85	72.18	22.50	6.00	135.00	54.00
8	Sulphur mill	45.00	7.00	315.00	126.00	44.76	8.00	358.08	153.97	45.00	7.00	315.00	126.00
9	Feeding mill	18.50	8.00	148.00	59.20	18.50	11.00	203.50	87.51	18.25	8.00	146.00	58.40
10	Extruder	37.00	8.50	314.50	125.80	37.00	11.00	407.00	175.01	38.00	8.50	323.00	129.20
11	Conveyor 1	0.37	8.50	3.15	1.26	0.37	11.00	4.07	1.75	0.35	8.50	2.98	1.19
12	Conveyor 2	2.00	8.50	17.00	6.80	2.00	11.00	22.00	9.46	2.10	8.50	17.85	7.14
13	R/Band cutter 1	2.00	8.00	16.00	6.40	2.00	16.00	32.00	13.76	2.10	8.00	16.80	6.72
16	R/Band Strainer 1	0.75	8.00	6.00	2.40	0.75	11.00	8.21	3.53	0.75	8.00	6.00	2.40
17	R/Band Strainer 2	0.75	8.00	6.00	2.40	0.75	11.00	8.21	3.53	0.75	8.00	6.00	2.40
19	Siliconning Machine	0.75	6.00	4.50	1.80	0.75	8.00	5.97	2.57	0.75	6.00	4.50	1.80
20	Bulbs	10.00	10.00	100.00	40.00	10.00	12.00	120.00	51.60	10.00	10.00	100.00	40.00
	Usage kW				738.06				978.50				741.27

Source: Compiled by author.



Graph 1. Productivity ratio.
Source: Compiled by author.

Table 11
Emission level against electricity usage.

Contaminant	Factory A	Factory B	Factory C
Total kWh consumption at factory, per month (kWh, 000)	18	29	18
CO_2 emission rate kg/1 kWh, per month (kg)	0.4	0.4	0.4
CH_4 factor	0.08	0.08	0.08
N_2O factor	0.03	0.03	0.03
CO_2 emission rate	7.38	11.74	7.41
CH_4 emission rate	1.48	2.35	1.48
N_2O emission rate	0.55	0.88	0.56
Total CO_2 emission level	9.41	14.97	9.45

Source: CO_2 Emission Factor – Sri Lanka Sustainable Energy Authority. N_2O, CH_4 Emission Factor – 2014 Climate Registry Default Emission Factors Released: January 10, 2014. Total Emission level – Compiled by author.

Table 12
Emission level against furnace oil usage.

Contaminant	Factory A	Factory B	Factory C
Furnace oil for rubber band lines (l) per month	7000.00	9500.00	7250.00
CO_2 emission rate kg/1 L of furnace oil, per month	2.900	2.900	2.900
CH_4 factor	0.022	0.022	0.022
N_2O factor	0.016	0.016	0.016
CO_2 emission rate	20.30	27.55	21.03
CH_4 emission rate	0.15	0.21	0.16
N_2O emission rate	0.11	0.15	0.12
Total CO_2 emission	20.57	27.91	21.30

Source: CO_2 Emission Factor – Sri Lanka Sustainable Energy Authority. N_2O, CH_4 Emission Factor – 2014 Climate Registry Default Emission Factors Released: January 10, 2014. Total Emission level – Compiled by author.

emission factor, CH_4 Factor, N_2O Factor, whereby arrival at total CO_2 emission level, CH_4 emission level and N_2O emission level multiplying the electricity usage. By adding CO_2, CH_4 and N_2O levels, total CO_2 emission level has been derived. Graph 2 portrays the emission rate of emission levels against electricity usage compared to each level of CO_2, CH_4 and N_2O and total CO_2 emission level.

4.6.3. *Emission level against furnace oil usage*

Data compiled from factory A, B and C, Table 12 shows the total furnace oil consumption per month, CO_2 emission factor, CH_4 factor and N_2O factor, whereby we arrive at a total CO_2 emission level, CH_4 emission level and N_2O emission level multiplying the electricity usage. By adding up of emissions of CO_2, CH_4 and N_2O levels, the total CO_2 emission level has been derived. Graph 3 indicates, the emission rates against furnace oil compared to each levels of CO_2, CH_4 and N_2O and total CO_2 emission level.

4.6.4. *Definition of life impact assessment and development of a calculation model*

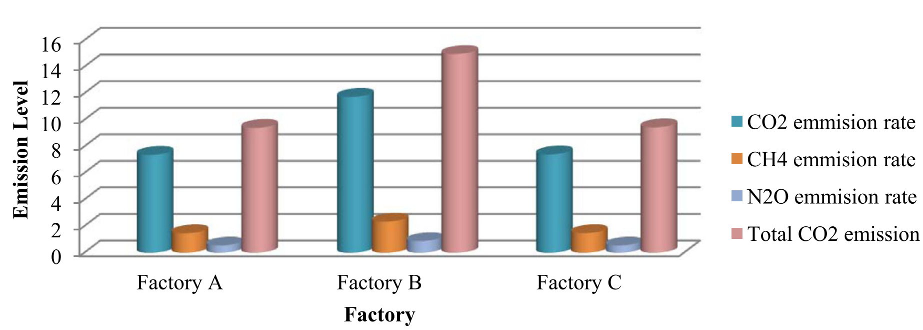
In the characterization stage of life impact assessment it is defined as the step in which the environmental interventions are translated in terms of contributions to a selected number of environmental impact categories.

$$\text{Impact Score}_{\text{category}} = \sum \text{Equivalency Factor}_{\text{category,type}} \times \text{Intervention Amount}_{\text{Type}}$$

Table 13
Global warming potential.

Substance	Global warming potential GWP_i (GWP_i in kg CO_2-equivalant/kg)
CO_2	1
CH_4	23
N_2O	296

Source: Calculation Details of GWP for the 2006 & 2015 Targets: A Study to Examine the Costs and Benefits of the ELV Directive – Final Report.



Graph 2. Emission level against electricity usage.
Source: Compiled by author.

In the rubber manufacturing process, mainly energy use is one of the primary production inputs as a production process. During this process, the substances emitted are CO_2 CH_4 and N_2O. Therefore, the Global Warming Potential is given in Table 13.

$$\text{Usage (kWh)} \times CO_2 \text{ emission factor (kgs } CO_2\text{/kWh)} \times 1 \text{ GWP ----------- (i)}$$
$$+$$
$$\text{Usage (kWh)} \times CH_4 \text{ emission factor (kgs } CH_4\text{/kWh)} \times 23 \text{ GWP --------- (ii)}$$
$$+$$
$$\text{Usage (kWh)} \times N_2O \text{ emission factor (kgs } CO_2\text{/kWh)} \times 296 \text{ GWP -------- (iii)}$$
$$=$$
$$CO_2 \text{ emissions (tons)}$$

Table 14 shows the total emission of CO_2 quantity per rubber band one ton per month. Result reveals total CO_2 emission from rubber band manufacturing in factory A, B and C respectively.

5. Concluding remarks

Being a vital role player in the economy, the SMEs are still reluctant to adopt energy-efficient and environmentally sound technologies due to their inherent characteristics and resistance to change. Environmental-friendly disbursements are associated with capital expenditure for implementing cleaner production model though they invest millions of dollars on pollution control equipment. Instead, firms espouse the cause of waste management that will benefit from financial savings in the long run.

Table 14
Total CO_2 emission level.

Contaminant	Factory A	Factory B	Factory C
Total CO_2 emission – electricity emission kg/kWh, per month	9.41	14.97	9.45
Total CO_2 emission – furnace oil emission kg/kWh, per month	20.57	27.91	21.30
Monthly rubber band production (ton)	25.80	28.00	25.00
Calculation	(9.41 + 20.57)/ 25.80	(14.97 + 27.91)/ 28	(9.45 + 21.30)/ 25
Emitted total CO_2-equivalent per rubber band 1 ton	1.16	1.53	1.23

Source: Compiled by author.

Review of literature shows that, there are several steps that have been taken to mitigate carbon footprint which affect global warming potential through sustainable production and country specific projects have been designed in mitigating carbon footprint, measurements to indicate carbon footprint levels at manufacturing processes which show that several efforts have been attempted to mitigate at global level. The impacts such as droughts, floods and landslides, typhoons/hurricanes, have marked variability and unpredictability of rainfall and precipitate patterns, increase in temperature; and sea-level rise, among many others. Further reviewing the related literature, researchers have observed factors affecting carbon footprint minimization as energy efficiency, cost of implementation, strategy for technical inputs, value of business, attitude of the owner, strategy of the owner, demand from stakeholders, government solution and government strategy.

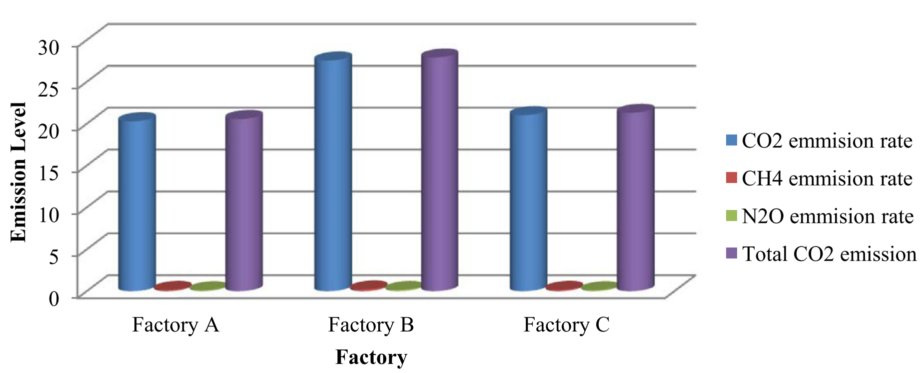
The research concludes testing of the SME attitudes that are supported by the data collected and minimization of energy-efficient carbon footprint. Major barriers of implementing energy-efficient carbon footprint mitigation measures in the SMEs in Sri Lanka reveal that, rank order of one to five of the Content Analysis of respondents.

A cause and effect chart such as fishbone analysis, provides a tool to identify all the possible causes of a problem — not just the obvious ones — This model helps to design and implement an active national policy framework along with energy-efficient carbon footprint effects which can play a bigger role when the enterprises are either not aware or negligent of carbon footprint mitigation measures.

It was discernible that a GWP due to GHG emission generated during the rubber-band manufacturing process, and uses of both electricity and furnace oil resulting in remittance of CO_2. In the course of finding out of a common method, the calculation model was preferred to quantifying carbon emission. This can be generalized as follows:

$$CO_2 \text{ Emission Level} = \text{Usage level (kW/H or liters)} \times CO_2 \text{ emission factor} \times (\text{kgs } CO_2/\text{kW/H or liters}) \times x\text{GWP}$$

Algebraically, when any unknown factor is to be found, we say, let it be '*x*' and build up on equation to prove it. Hence in this research the missing factor is the intervention of GWP. According to the information gathered from factories A, B and C, the usage level of energy is derived as monthly rubber band production amounting to (ton) 25.80, 28.00, 25.00 respectively. Productivity ratios of the three factories were 67.40, 46.28 and 64.16 respectively. Accordingly, total CO_2 emissions from electricity consumption per month are 9.41, 14.97 and 9.45. The total CO_2



Graph 3. Emission level against furnace oil usage.
Source: Compiled by author.

emissions from electricity consumption per month are 20.57, 27.91 and 21.30. As a result, the total CO_2 emission from rubber band manufacturing amounts to 1.16, 1.53 and 1.23 ton CO_2-eq/ton product in factories A, B and C respectively. Thus, the above assumption logically leads to identify the factory specific amount of carbon footprint emission and development of sustainable production model which will benefit the economy and finally the environment. Researchers hope this study will be a forerunner for all rubber producing countries to identify challenges and barriers for application of cleaner manufacturing model. This is not only an instance in point applicable to Sri Lanka, but also the research findings are to be directly benefited by any country where rubber production on a commercial scale is taking place, whilst identifying the relevance of global warming potentials and especially, the SMEs to calculate carbon emission level, find alternatives to minimize energy-efficient carbon footprint effect and sustainable production.

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Extract of the questionnaire

A questionnaire is developed for the industrialists comprising three areas. In the first part, it shows the name of the company, the type of production, the number of employees, the monthly production turnover and the district.

Part two consists of the main factors with questions to be answered in the form of Likert scale. The first statement of energy efficiency incorporates questions regarding obtaining ISO 50000 certification ensuring energy efficiency, importance of employee awareness of energy efficiency, application of cleaner production in the production process that will ensure energy efficiency, application of cleaner production in production process will ensure energy efficiency, poor implementation of CSR in energy sector and high energy demand by the industry.

The second main factor of cost of implementation of strategies comprises questions regarding high implementation cost, high cost energy saving techniques are high, high cost of present waste collection and disposal systems, high cost of introduction of municipal composting methods and high cost of recycled raw materials.

The third main factor of strategy for technical inputs comprises questions of reuse and reduction of high cost waste plans, recycling options for manufacture useable reproduction materials, use of high cost technical assistance to implement strategies, applying green supply chain management strategy, reuse and reduction of high cost waste plans and applying green supply chain management strategy.

The fourth main factor is regarding value of the business. It comprises questions of cost reduction methods that increase the value of business, green supply chain that will increase the production cost, increasing the customer loyalty towards the product by green labelling, cleaner production mechanism that will increase the business value, endorsing of fair trade certification that will increase value of the business and making available of green building that will increase the value of the business.

The fifth main factor is about the attitude of the owner which comprises questions of how important is participation to conserve resources, system adopted to participate in 3R process, how important is information dissemination to raise workers' awareness, how important is employers' motivation to apply carbon footprint reduction measures, the importance of obtaining ISO 14001, the importance of the use of efficient machineries on a regular basis, the importance of regular maintenance of machinery, importance of managers knowledge effective intervention in production mix, lethargic pattern of purchase that does not support to reduce carbon footprint and low knowledge of availability of alternative heating and lighting systems.

The sixth main factor of strategy of the owner comprises questions based on the importance of owner's participating in the 3R process, employees' participation in 3R issues, developing partnerships with stakeholders to minimize carbon footprint, sound establishing of corporate strategy adopted to minimize carbon footprint and apply cleaner production technique.

The seventh main factor of demand from stakeholders comprises questions about energy labelling for products required, social contracts that enhance the required public image, high customer perception on low carbon emission products, high customer purchasing behavior/pattern that increases carbon footprint, agreed framework for calculating a carbon footprint and less knowledge of role of national cleaner production centre.

The eighth main factor is regarding the importance of government solutions. It comprises questions of law enforcing authorities' intervention to find a solution, forcing the government to implement important laws, effective intervention of solid waste management, implementing GRI standards to industries and setting up of vision, formulating of mission and objective for emission minimizing measures at national level for industries.

The ninth main factor is government strategy. It comprises questions of the importance of acting of a law concerning the promotion of procurement of eco-friendly goods and services, government acting as a change agent, developing legal framework to apply compulsory cleaner production mechanism, implementing GRI standards to industries, enforcing the industry and government agencies to work together and support mechanism to low carbon footprint emitting SMEs.

The dependent variable of carbon footprint minimizing comprises questions of carbon footprint minimizing leading to reduction of global warming and a tri-parities engagement is important. The industry should be transparent regarding carbon emission. Industry knowledge on CDM policy is important and awareness of Kyoto Protocol playing major role.

Part three of the questionnaire is left open to provide any answers not provided in the above two sections.

Another questionnaire is being developed to gather industry experts' opinion. In the first section, researcher gathered general information: name of the respondent, occupation and duration of the industry they had engaged in. The second section consists of the information related to Global Warming Potential. Questions that raised were: what is your general opinion about GWP. How does it relate to rubber industry? What methodology should be used in the rubber manufacturing process to minimize GWP? What is the opinion about energy consumption by the industry? How much CO_2 do you think rubber milling process emit? How do you suggest minimizing carbon dioxide emission and any other views in this connection?

Third section of the questionnaire consists of their opinion and ranks judgement from one to ten (1–10) in the following fields.

Type of issue	Yes	No	Rank
Need of an active national policy for cleaner production			
Awareness on energy-efficiency in industries			
Tri-partite agreement required			
Awareness on role of the National Cleaner Production Centre			
Attitude of the owner to minimize carbon footprint			
Awareness programs on carbon footprint minimizing			
Implementation cost of carbon footprint reduction measure are high			
Less carbon consultants available in the market			
No carbon trading mechanism in the market			
Value of the business relating to the emission of carbon			

References

Agan, Y., Acar, M.F., Borodin, A., 2013. Drivers of environmental processes and their impact on performance: a study of Turkish SMEs. J. Clean. Prod. 51, 23–33.
2014 Climate Registry Default Emission Factors, January 10, 2014.
Baranzini, A., Goldemberg, J., Speck, S., 2000. A future for carbon taxes. Ecol. Econ. 32, 395–412.
Batuwitage, L.P., 2011. Sustainable Production and Consumption Model for Sri Lanka: Developing Country Perspective in Relation to Global Change (Thesis to obtain the degree of doctor from the Erasmus University Rotterdam).
Braun, P., 2010. Going green: women entrepreneurs and the environment. Int. J. Gen. Entrep. 2 (3), 245–259.
Brenton, P., Jones, G.E., Jensen, M.F., 2009. Carbon labelling and low-income country exports: a review of the development issues. Dev. Policy Rev. 27 (3), 243–267.
Calculation Details of GWP for the 2006 & 2015 Targets: A Study to Examine the Costs and Benefits of the ELV Directive – Final Report.
Fore, S., Mbohwa, C.T., 2010. Cleaner production for environmental conscious manufacturing in the foundry industry. J. Eng. Des. Technol. 8 (3), 314–333.
Gallup, J., Marcotte, B., 2004. An assessment of the design and effectiveness of the environmental pollution prevention project. J. Clean. Prod. 12, 215–225.
Gilbert, P., Alexander, S., Thornley, P., Brammer, J., 2014. Assessing economically viable carbon reductions for the production of ammonia from biomass gasification. J. Clean. Prod. 64, 581–589.
Gunathilaka, L.F.D. de Z., Gunawardana, K.D., 2014. Analysis of Carbon-off Setting Targets Towards Sustainable Economic Development in Apparel Sector Organization in Sri-Lanka. International Conference on Environmental Science and Development – ICESD.
Guinée, J.B., Heijungs, R., 1995. A proposal for the definition of resource equivalency factors for use in product life-cycle assessment. Environ. Toxicol. Chem. 14 (5), 917–925.
Hoque, A., Clarke, A., 2013. Greening of industry in Bangladesh: pollution prevention practices. J. Clean. Prod. 51, 47–56. DOI. http://dx.doi.org/10.1016/j.jclepro.2012.09.008.
International Labour Organization, Assessing Green Jobs Potential in Developing Countries – A Practitioner's Guide, 2011.
IPCC, 2007. Synthesis Report.
Jayawardena, C., 2013. Innovative solutions for future tourism development in Sri Lanka (2013–2026). Worldw. Hosp. Tour. Themes 5 (5), 512–531.
Jawjit, W., Kroeze, C., Jawjit, S., 2010. Quantification of Greenhouse Gas Emissions from Primary Rubber Industries in Thailand. Greening of Industry Network (Gin) 2010: Climate Change and Green Growth: Innovating for Sustainability.
Jensen, J.K., 2012. Product carbon footprint developments and gaps. Intern. J. Phys. Distrib. Logist. Manage. 42 (4), 338–354.
Jegannathan, K.R., Nielsen, P.H., 2013. Environmental assessment of enzyme use in industrial production – a literature review. J. Clean. Prod. 42, 228–240.
Kirchoff, J.F., Koch, C., Nichols, B.S., 2011. Stakeholder perceptions of green marketing: the effect of demand and supply integration. Int. J. Phys. Distrib. Logist. Manag. 41 (7), 684–696.
Lee, S.M., Kim, S.T., Choi, D., 2012. Green supply chain management and organizational performance. Ind. Manag. Data Syst. 112 (8), 1148–1180.
Liu, Y., Fang, Y., He, R., 2011. Construction of regional industrial systems cleaner production integrated evaluation model and its application. Proc. Environ. Sci. 10, 2112–2117.
Loucks, E.S., Martens, M.L., Cho, C.H., 2010. Engaging small- and medium-sized businesses in sustainability. Sustain. Account. Manag. Policy J. 1 (2), 178–200.
Malhotra, N.K., 2005. Marketing Research: an Applied Orientation, vol. 5. Prentice Hall of India (Pvt.) Ltd., New Delhi.
Manaktola, K., Jauhari, V., 2007. Exploring consumer attitude and behaviour towards green practices in the lodging industry in India. Int. J. Contemp. Hosp. Manag. 19 (5), 364–377.
Menzel, V., Smagin, J., David, F., 2010. Can companies profit from greener manufacturing? Meas. Bus. Excell. 14 (2), 22–31.
Morfeldt, J., Nijs, W., Silveira, S., 2014. The impact of climate targets on future steel production – an analysis based on a global energy system model. J. Clean. Prod. 1–14.
National Strategy for Small & Medium Industries Development in Sri Lanka, 2002. Ministry of Industry and Commerce, Colombo, Sri Lanka.
Nelson, T., Wood, E., Hunt, J., Thurbon, C., 2011. Improving Australian greenhouse gas reporting and financial analysis of carbon risk associated with investments. Sustain. Account. Manag. Policy J. 2 (1), 147–157.
Perry, S., Klemes, J., Bulatov, I., 2008. Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors. Energy 33 (10), 1489–1497.
Phillips, J., 2013. Using fishbone analysis to investigate problems. Nurs. Times 109 (15), 16.04.13.
Röös, E., Tjärnemo, H., 2011. Challenges of carbon labelling of food products: a consumer research perspective. Br. Food J. 113 (8), 982–996.
Santoyo-Castelazo, E., Azapagic, A., 2014. Sustainability assessment of energy systems: integrating environmental, economic and social aspects. J. Clean. Prod. 80, 119–138.
Shi, V.G., Koh, S.C.L., Baldwin, J., Cucchiella, F., 2012. Natural resource based green supply chain management. Supply Chain Manag. Int. J. 17 (1), 54–67.
Singh, R.K., Garg, S.K., Deshmukh, S.G., 2010. Strategy development by small scale industries in India. Ind. Manag. Data Syst. 110 (7), 1073–1093.
Tellis, W., 1997. Application of a case study methodology. Qual. Rep. 3 (3). Available at: http://www.nova.edu/ssss/QR/QR3-3/tellis2.html (accessed 05.03.13).
The Global Transition – The Green Economy, 2012. Earth Summit Held in 2012 in Rio de Janeiro.
The Impact of the Global Crisis on SME and Entrepreneurship Financing and Policy Responses, 2009. Centre for Entrepreneurship, SMEs and Local Development (OECD).
Thiruchelvam, M., Kumar, S., Visvanathan, C., 2003. Policy options to promote energy efficient and environmentally sound technologies in small- and medium-scale industries. Energy Policy 31, 977–987.
Tuttle, T., Heap, J., 2008. Green productivity: moving the agenda. Int. J. Prod. Perform. Manag. 57 (1), 93–106.
A Greener Footprint for Industry: Opportunities and Challenges of Sustainable Industrial Development, 2010. UNIDO, Vienna.
United Nations Environmental Programme, 1997.
UNIDO, 1998. Seminar on Energy Conservation in Rubber Industry, 1998.
Visvanathan, C., Norbu, T., 2006. Reduce, reuse, and recycle: the 3Rs in South Asia. In: Presented at 3 R South Asia Expert Workshop, 30 August–1 September, 2006, Kathmandu, Nepal.
Warren-Meyer, G., 2012. The value of sustainability in real estate: a review from a valuation perspective. J. Prop. Invest. Finance 30 (2), 115–144.
Wyk, E.V., 2010. Tax incentives for biodiversity conservation in the Western Cape. Meditari Account. Res. 18 (1), 58–75.
Ze-hua, M., Na, B., Li, D., Wen-bo, S., 2011. Exploring execution of ecological engineering and cleaner production in pharmaceutical industry. Energy Proc. 5, 679–683.

Web references

http://www.horanaplantations.com/History-of-Rubber.html (accessed 12.09.13).
http://www.kew.org/science-conservation/plants-fungi/hevea-brasiliensis-rubber-tree (accessed 12.09.13).
http://www.srilankaheritages.com/henarathgoda.html (accessed 12.09.13).

Abbreviation

CDM: clean development mechanism
CEB: Ceylon electricity board
CER: certified emissions reductions
CH_4: methane
CML: centre of environmental science
CO_2: carbon dioxide
CoP: conference of parties
CP: cleaner production
E^3ST: energy, efficiency and environmental sound technology
EMS: environmental management systems
EREC: European renewable energy council
EU: European Union
GDP: gross domestic product
GHG: greenhouse gas
HFCs: hydro fluoro carbon
IEA: international energy agency
ILO: international labour organization
IPCC: inter-governmental panel on climate change
IPP: integrated product policies
ISO: international standards organization

LCA: life cycle analysis
LIES: locally integrated energy system
LPG: liquefied petroleum gas
N_2O: nitrous oxide
NCPC: national cleaner production centre
OECD: organization for economic corporation and development
PFCs: per fluorocarbons
R&D: research and development
RECP: resource efficient and cleaner production
RMU: removal units
SF_6: sulphur hexafluoride
SME: small and medium scale enterprises
UNEP: United Nations Environment Programme
UNFCCC: United Nations framework convention on climate change
UNIDO: United Nation industrial development organization
WMO: world meteorological organization