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Framework and methods to quantify carbon footprint based on an office environment in Singapore

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ABSTRACT

A framework and set of methods to provide quantification of carbon footprint for an office in Singapore is presented in this work. As office operations become the center of many organization's activities, a rising awareness of climate change puts the focus on the carbon footprint of office operations. Various international standards have provided guidelines in assessing the carbon footprint of organizations. However, a lack of explicit formulation and procedure in these standards makes them difficult to apply. Furthermore, organizations that are just starting to assess their footprint may not have the resources and trained personnel to perform a full-scale assessment. To fill this gap, the framework proposed in this paper categorizes the emission sources from an office into several categories: core devices, shared resources, pantry, and transportation; and a set of quantification methods then guide the practitioner in a visual manner to do their office carbon footprint. A case study was conducted with an organization in Singapore. Results showed that the organization has a monthly office carbon footprint of 2306.57 kg CO_2e, with major emissions coming from the air-conditioning system and private car usage. The study showed that the method can be used to assess the overall emissions, as well as identifying the major emission sources.

1. Introduction

Human activities, such as the burning of fossil fuels for energy, agricultural activities and the release of aerosols have led to the release of anthropogenic greenhouse gases into the atmosphere. These greenhouse gases, mentioned in the Kyoto Protocol (Carbon Trust, 2012) are widely known to be the major cause of global warming.

Previous reports from the Intergovernmental Panel on Climate Change have highlighted the correlation between the increase of CO_2 emissions and climate change (IPCC, 2013). To illustrate the magnitude of the problem, in U.S. alone the CO_2 emission from fuel combustion reached more than 5.3 billion ton CO_2 equivalent, and almost 40% of that value comes from electricity generation (U.S. Environment Protection Agency, 2014). Fortunately, as society prospers, there is an increasing awareness of the environmental impact of this crisis.

Carbon footprint (CFP) is a term used to describe the measurement of greenhouse gas emissions from an individual, product, or organization. Wiedmann (2007) defined CFP as the emissions of CO_2 which was caused both directly and indirectly by an activity during the whole lifecycle of a product. However, as most activities may also emit other greenhouse gases, the definition of CFP should be extended to account for these gases. Thus, the term carbon dioxide equivalent (CO_2e) is commonly used in CFP assessments. Equivalent here means that the global warming factor of greenhouse gases other than CO_2 is calculated to show their potential compared to that of CO_2, and included in the assessment.

Singapore, being a major business hub in Southeast Asia, is also active in promoting environmental awareness, and realized climate change will disrupt their economic activities (National Climate Change Secretariat, 2013). Thus, it is beneficial to develop a methodology to calculate CFP for organizations with offices as their center of operations in Singapore. Taking organizations just starting CFP assessment into consideration, the work presented here aims to fill the gap in having a practical method to conduct a CFP assessment for the office activities of an organization based in Singapore. The technique of using a framework and a guided

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method is preferred due to its ability to illustrate the parameters needed and how they are used in a calculation. Thus, through the technique presented in this work it is envisioned that more institutions will contribute in promoting environmental awareness.

This paper starts with a brief introduction into the need for a CFP assessment method for office operations, and follows by a detailed description of the method. A case study to show the applicability of the method is conducted, and the results and discussion of the study is presented. A conclusion will close the work at the end.

2. Literature review

2.1. Previous works and governing standards

In conducting a CFP assessment the work may be based on various governing international standards and methods of calculation, as presented in the work of Pandey et al. (2011). The assessment itself may be applied to different domains: such as to an institution (Guereca et al., 2013; Larsen et al., 2013; Meida et al., 2013), hotels and tourism (El Hanandeh, 2013; Filimonau et al., 2014, 2011), households (Kenny and Gray, 2009; Onat et al., 2014; Shirley et al., 2012), airports (Postorino and Mantecchini, 2014), production processes and technologies (Ng et al., 2015a; 2015b; 2014a; 2012; 2011, Shi et al., 2012; 2011a; 2011b), and waste management (Ng et al., 2014b; 2014c; 2011; Rugrungruang et al., 2009; Yang et al., 2010). These studies implement international standards as a foundation of their work (Guereca et al., 2013; Meida et al., 2013; Ng et al., 2014b; 2014c; 2011) and employ various methods of assessments, with Life Cycle Assessment being the most common (Filimonau et al., 2011; Onat et al., 2014; Shirley et al., 2012).

Other than the areas of study mentioned above, several studies focus on the area of organization CFP; as presented in the works of Alvarez et al. (2014), Aroonsrimorakot, et al. (2013), Guereca et al. (2013), Larsen et al. (2013), Meida et al. (2013), and Onat et al. (2014). These studies utilize calculation methods such as the Environmental Extended Input-Output (EEIO) modeling (Larsen et al., 2013), and Compound Method for Financial Accounts (CMFA) (Alvarez et al., 2014). In general, the cited works in the area of organization CFP refers to the Greenhouse Gas (GHG) Protocol (WRI WBCSD, 2004) as a defining standard.

In providing a general outline to conducting a CFP assessment, several international standards are available, such as the ISO 14064-1 (ISO, 2006), ISO/TS 14067 (ISO, 2013), PAS 2050 (BSI, 2011a, 2011b), and the Greenhouse Gas (GHG) Protocol (WRI WBCSD, 2004). These standards cover two major type of CFP assessment: product and organization CFP. Product CFP quantifies the emissions covering the activities of the whole product's life-cycle (BSI, 2011a; ISO, 2013); while organization CFP quantifies the emissions from an organization's activities (ISO, 2006; WRI WBCSD, 2004).

Of all the standards on organization CFP, the GHG Protocol (WRI WBCSD, 2004) is an international standard commonly referred to in the cited works. Based on this standard, an assessment is required to report the emissions occurring within an organization through three scopes: direct emissions from the organization's activities (Scope 1), indirect emissions from the purchased electricity (Scope 2), and other indirect emissions caused by personal transportation and consumption of goods and services (Scope 3). Being a universally-accepted standard, the GHG Protocol provides a high level view on the required emissions to be reported. However, as a consequence, the standard placed less emphasis on how the emissions should be calculated.

Other than the GHG Protocol, another commonly adopted standard in CFP assessment is the Publicly Available Specification (PAS) 2050 (BSI, 2011a, 2011b) as exemplified in the works of Chen et al. (2013), Garcia and Freire (2014), Hassard, et al. (2014) and Ng et al. (2014b; 2014c; 2011). However, this standard is meant for the assessment of goods and services, and thus takes a different approach from that of an organization CFP assessment. Still, the PAS 2050 provides a more detailed guidance in calculating the emission from a process and consumption of goods. Based on this standard, to calculate emission from an activity or process, two main parameters are needed. First is the activity data (AD), which shows the quantification of the process. Depending on the activity, a unit of measurement is assigned to the activity data. For example, for an activity involving the consumption of electricity, the unit may be in the form of kilowatt-hour (kWh); while transportation activities may be measured in terms of kilometer (km); or passenger-kilometer (passenger-km), normalizing the distance travelled per passenger. The other parameter needed is the emission factor (EF). This parameter shows how much emission, in CO_2 equivalent, is being emitted for a unit of the activity data. Emission factor values may be found from direct measurement of processes, or from publicly available data such as the GHG conversion factors from UK's Department of Environment, Food, and Rural Affairs (2012), and the Inventory of Carbon and Energy by Hammond and Jones (2011). Equation (1) illustrates the method to calculate the CFP of a process or consumption of goods.

$$CFP = \sum (AD_i \times EF_i) \quad (1)$$

Where:

CFP: Carbon footprint arising from a process or consumption of goods (kg CO_2e).
AD_i: Activity data from source *i* (based on a unit of measurement).
EF_i: Emission factor for source *i* (kg CO_2e/unit of measurement).

By taking the quantification principle of PAS 2050 down to its basic purpose; which is to calculate emissions from activities and consumptions, this method may be used to complement the gap on how to calculate emissions in a corporate CFP assessment.

2.2. Limitations of comprehensive methods and standards

The methods used in the previous works, such as the EEIO and CMFA, are very comprehensive in both the execution and results, and require an expert trained in those areas. Such complexity may be daunting for a practitioner just starting in their study of CFP assessment. Very often organizations who wish to contribute in promoting environmental awareness by performing their own CFP assessment are lacking in resources and capabilities; this is especially true in the case of small and medium enterprises (SMEs). Furthermore, the governing standards provide only a general outline on the procedure of conducting a CFP assessment. The standards emphasized more on *what* to be included in a CFP assessment report, and less on *how* to execute it. Therefore, to assist organizations starting on CFP assessment a relatively straightforward technique is needed.

2.3. Objective of the proposed method

To address the need of such a technique, the application of a set of guided-based method to quantify the emission of a source with an underlying framework to group the emission sources is proposed in this work. The proposed method presents a practical way to conduct CFP assessment of organizations which has offices as base of operations in Singapore. Practicality, without sacrificing

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