Vegetable Industry Carbon Footprint Scoping Study

Discussion Paper 1

What is a Carbon Footprint? An overview of definitions and methodologies

by Andrew John East
Growcom

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Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

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Purpose of the paper:

The purpose of this paper is to define a "carbon footprint" and provide an insight into the terminologies and approaches included within this concept. A number of key issues are addressed in this discussion.

Firstly, the origins of the "footprinting concept" are addressed to establish the conceptual history (and baggage) associated with this term. Secondly, existing literature is critiqued to scope the various definitions, highlight distinctions and articulate a preferred definition of a carbon footprint. Thirdly, key methodological steps involved in the calculation of a carbon footprint are addressed. Lastly, recommendations of this study are presented, linking the broader debate on "what is a carbon footprint" with implications for the development of a footprinting tool in the Australian Horticultural industry.

Funded by Horticulture Australia Limited
HAL Project Manager – Alison Turnbull, Natural Resources & Climate Manager alison.turnbull@horticulture.com.au

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Summary

The term “carbon footprint” has gained increased popularity in recent years and is now widely used in government, business and the media. Although extensively used in the public domain, further investigation shows that this term has not been adequately defined in scientific literature. As such a large range of definitions exist for this term. Despite the lack of scientific endorsement, the term carbon footprint has quickly become a widely accepted “buzz word” to further stimulate consumers’ growing concern for issues related to climate change by describing anything from the narrowest to the widest interpretation of greenhouse gas measurement and reduction. In general, distinctions in the literature are primarily focused on two key issues: units of measurement and scope of measurement.

The following definition of a carbon footprint has been adopted in this paper based on a discussion of existing literature:

> **A direct measure of greenhouse gas emissions (expressed in tonnes of carbon dioxide [CO_2] equivalents) caused by a defined activity. At a minimum this measurement includes emissions resulting from activities within the control or ownership of the emitter and indirect emissions resulting from the use of purchased electricity.**

In general, the term carbon footprint is associated with a less rigorous, consumer oriented, popularised concept of greenhouse gas reductions for the purpose of marketing the benefits of less emission intensive products and services. On the other hand, the term greenhouse gas accounting is tailored towards a more rigorous measurement of greenhouse gases for the purpose of calculating and reducing a company’s greenhouse gases. While there is no question of the popularity of the term carbon footprint, the suitability of its use in association with measuring greenhouse gas emissions in horticulture is more questionable. Depending on the purpose of the investigation, alternative terms such as “greenhouse gas accounting” may be more appropriate.

Regardless of the term that is used, at a minimum a tool to measure greenhouse gases from horticultural production systems should:

- Be developed with close reference to the underlying rationale for the importance of such a tool in the horticultural industry.
- Measure and report on emissions that result from practices directly controlled or owned by the unit (country, company, person, etc.) under investigation.
- Measure and report on all six greenhouse gases covered in the Kyoto protocol expressed in terms of the warming potential of CO_2.

1.0 Introduction

The term "carbon footprint" has grown in popularity over the past ten years in response to the increasing public awareness of environmental issues and climate change. This phrase is now widely used throughout the media, government and commercial world. The popularity of this concept is intrinsically linked to concern about increasing levels of CO_2in the earth's atmosphere and the belief that increasing concentrations of CO_2have and will continue to alter the earth's climate (IPCC 2007). But what actually is a "carbon footprint"? Despite this term's extensive use in the media, government and in the commercial world, deeper analysis shows that the prolific use of this term has not been accompanied by a universally agreed definition.

This paper discusses the definition of a carbon footprint to define this term as:

> A direct measure of greenhouse gas emissions (expressed in tonnes of CO_2 equivalents) caused by a defined activity. At a minimum this measurement includes emissions resulting from activities within the control or ownership of the emitter and indirect emissions resulting from the use of purchased electricity.

2.0 Tracing the origins of the carbon footprinting concept

The use of the term "footprint" to describe the impact of human production or consumption activities was first developed by planners at the University of British Columbia, William Rees and Mathis Wackernagel. In this way, Wackernagel and Rees (1996) define an "ecological footprint" as an accounting tool used to measure the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area. The ecological footprint concept is still widely used today as a resource management tool (Global Footprint Network 2007).

The term "carbon footprint" originated from the ecological footprint concept but in recent years has evolved into a concept in its own right. In this way, while a universally agreed definition of a carbon footprint is yet to exist, key discernable differences between these terms are apparent. In general, a carbon footprint focuses on processes and practices related to the emission of CO_2 (and other greenhouse gases). This is in contrast to the broader range of ecological impacts resulting from human action included within the concept of an ecological footprint. Secondly, while an ecological footprint is a measure of the regenerative capacity of the environment (expressed in a corresponding area of productive land), the majority of definitions for a carbon footprint measure a physical quantity of carbon (or equivalent gases) resulting from defined activities. Despite this divergence, these two concepts retain a general connection due to their measurement of environmental impact of human production or consumption activities.

3.0 The range of definitions on a carbon footprint

Many definitions of the term carbon footprint exist. These definitions are however largely based on publications from "grey" (popular) rather than scientific literature. A literature search on 15 September 2008 of all journals included within the international database 'ScienceDirect' found 31 sources where "carbon footprint" appeared in the title, abstract or keywords of an article. Of these results 24 articles were published in 2008 and seven in 2007. Despite the large number of recent publications, these articles primarily focus on measuring and reducing greenhouse emissions of particular processes and products and do not adequately address more fundamental definition issues.

The lack of scientific literature on the conceptual definition of a carbon footprint is contrasted by the overwhelming amount of information available on carbon footprints in the public domain. A Google search for the term "carbon footprint" found over four million sites, many with their own definition of this term. The lack of scientific literature on the conceptual definition of a carbon footprint suggests some disparity between the popularised understanding of a carbon footprint and the scientific processes typically associated with peer reviewed journals. In this way, one author comments that it is conceptually incorrect to measure a carbon footprint in tonnes of CO_2 because footprints are spatial indicators, measured in hectares or square metres (Hammond 2007). For this reason Hammond (2007) states that a more appropriate term would be "carbon weight". Similarly, Wiedmann and Minx (2007) comment that an estimation tool that includes the measurement of greenhouse gases in addition to CO_2 would be more appropriately called a "climate footprint" rather then a "carbon footprint".

However the apparent lack of scientific endorsement has not prevented the increasing use of this term in publications by government, media and businesses. For example, the United Kingdom supermarket chain Tesco has responded to a perceived increasing consumer awareness of environmental issues by trialling a new carbon labelling scheme that reports on the "carbon footprint" for a variety of products. In this scheme customers are advised of the number of grams of carbon or equivalent greenhouse gasses emitted as a result of growing, manufacturing, transporting and storing a product. The trial includes labelling 20 of Tesco's band owned products (including laundry detergent, orange juice, potatoes and light bulbs) with on pack "footprint labels". The calculation includes the impact of preparing or using a product and then disposing of any waste used in manufacturing processes. Many of the labels will also inform shoppers how a product's carbon footprint compares with other similar products, so customers can tell which has the smallest carbon footprint (Tesco 2007).

A sample of range of definitions in the grey literature can be seen in Table 1.

Table 1: various definitions of a carbon footprint in the "grey literature"

"The carbon footprint therefore measures the demand on biocapacity that results from burning fossil fuels in terms of the amount of forest area required to sequester these CO_2 emissions" (Global Footprint Network 2007).
"The term carbon footprint is commonly used to describe the total amount of CO_2 and other greenhouse gas (GHG) emissions for which an individual or organisation is responsible. Footprints can also be calculated for events or products" (Carbon trust 2008).
"The carbon footprint is a measure of the exclusive total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann & Minx 2007).
"A measure of the amount of CO_2 emitted through the combustion of fossil fuels; in the case of an organisation or business, it is the CO_2 emissions due to their everyday operations; in the case of an individual or household, it is the CO_2 emissions due to their daily activities; for a product or service, it includes additional life-cycle CO_2 emissions along the supply chain; for materials, it is a measure of the embodied CO_2 emissions determined through life cycle assessment" (Carbon N Zero 2008).
"A measure of the amount of CO_2 emitted through the combustion of fossil fuels. A carbon footprint is often expressed as tons [sic] of CO_2 or tons [sic] of carbon emitted, usually on an annual basis" (TreeVestors 2008).
"This term actually refers to the amount of productive land (forest) required to

sequester (remove) the equivalent amount of GHGs that a company emits" (Triplepundit 2008).
"The total amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a product or service" (MCI 2008).

Due to the lack of a universally accepted definition of a carbon footprint a variety of alternative terms have been developed to define similar concepts or processes. Such terms include "greenhouse gas accounting" (Forsyth & Oemcke 2007), "greenhouse gas calculation" (Institute of Sustainable Resources 2007) and "carbon accounting" (Swinburne University of Technology 2008). The phrase "carbon calculator" is also used to describe the measurement of CO_2 emissions from fuel and energy sources and/or production processes (Carbon N Zero 2008). The terminology in rigorous internationally recognised accounting protocols such as International Organisation for Standardisation (2006) and World Resource Institute and World Business Council for Sustainable Development (2008) indicates that increasing accuracy of emissions accounting is more associated the term "greenhouse gas accounting" and not "carbon footprint".

In summary, the term carbon footprint has become a "buzz word" to encapsulate, stimulate and engage consumers' concern for issues related to climate change by describing anything from the narrowest to the widest interpretation of greenhouse gas measurement and reduction. The popularity of this term has come despite the many different and often times conflicting definitions and the general lack endorsement of the term "carbon footprint" in scientific literature.

4.0 Identifying a generally accepted definition of a carbon footprint for use in horticultural industries

The large volume of literature on carbon footprints and other associated concepts (greenhouse gas accounting) provides a valuable starting point from which to develop a generally accepted definition of this term. While the extensive literature in the public domain has not been subjected to the rigour of peer review process, a number of well researched and scientifically based sources do exist (Carbon trust 2008; Garnett 2006; Lillywhite et al. 2007; Wiedmann & Minx 2007; World Resource Institute & World Business Council for Sustainable Development 2008). In general, distinctions in the literature are primarily focused on two key issues: units of measurement and scope of measurement.

4.1 Units of measurement

Identifying the units of measurement of a carbon footprint requires that a position be reached on two key questions.

The first relates back to the distinction between an ecological footprint and a carbon footprint: should the measurement of a carbon footprint be expressed in tonnes of gaseous emissions or in area-based units tied to the natural regenerative capacity of the environment? On this issue, the majority of definitions of a carbon footprint in the grey literature recognise the connection between a carbon footprint and the measurement of gaseous emissions.

Assuming that a carbon footprint should be measured in tonnes of gaseous emissions brings about a second definition issue: should the measurement of a carbon footprint be in tonnes of CO_2 or should it be extended to include a variety of greenhouse gases expressed in tonnes of CO_2 equivalents? To understand this issue, a broader understanding of tools and mechanisms

to reduce greenhouse gases, as set out in international agreements such as the Kyoto protocol, is required.

The Kyoto protocol is a legally binding international agreement between signatory nations to the United Nations Framework Convention on Climate Change (UNFCCC) to reduce greenhouse gases and of the stabilisation of anthropogenic greenhouse gas emissions. Measuring the warming potential of differing greenhouse gases in CO_2equivalents is central to the emissions accounting framework of the Kyoto protocol.

According to the Kyoto protocol, there are six main greenhouse gases with the potential to cause climate change, each with a different global warming potential. For simplicity of reporting, the warming effect of CO_2 has been assigned a value of one and the global warming potential of the other greenhouse gases are used to convert the non-carbon dioxide gases to CO_2 equivalents (CO_2 -e) (Carbon N Zero 2008). The warming potential of each of these gases over 100 years can be seen in Table 2.

Table 2: global warming potential of different green house gases covered in the Kyoto Protocol

Gas	Warming potential	Source
Carbon dioxide	1	Mainly from fossil fuel use
Methane	21	Mainly from ruminant animals and organic waste
Nitrous oxide	310	Mainly from agriculture
Hydrofluorocarbons	140 to 11,700	Mainly from refrigerants
Perfluorocarbons	9,200 to 6,500	From aluminium production
Sulphur hexafluoride	23,900	Mainly from the electricity industry

Source: Department of Climate Change (2008a)

Various nations have commenced or are in the process of designing an emissions trading scheme to assist in reducing emissions and meeting emission reduction targets under the Kyoto protocol. Emissions trading schemes already exist in Europe and will soon commence in Australia and New Zealand.

The weight of evidence regarding the second question on units of measurement suggests that a carbon footprint should include measurement of a variety of greenhouse gases expressed in CO_2 equivalents. This would ensure the activity being "footprinted" is consistent with the requirements to report on multiple gases in international agreements such as the Kyoto Protocol. Aligning the measurement requirements of a carbon footprint to cover multiple greenhouse gases would ensure synergy between emission accounting practices and avoid confusion in the public domain. Further detail on a connection between a carbon footprint and an emissions trading scheme will be discussed in the second paper in this series.

4.2 Scope of measurement

Establishing the boundaries for measuring a carbon footprint is a necessary to ensure the accuracy of a footprinting approach. This raises the issue of whether the measurement of a carbon footprint should include indirect emissions embodied in upstream production processes or only direct emissions within an organisational boundary?

To help delineate "direct" and "indirect" emission sources, improve transparency, and provide utility for different types of organisations, different "scopes" of emissions (scope one, scope two, and scope three) are frequently used (World Resource Institute & World Business Council for Sustainable Development 2008). These scopes have been designed to ensure a company will not count emissions twice and to enable emissions to be traced across the economy.

Scope one emissions relate to direct emissions occurring within the organisational boundary of a company. Two approaches exist for determining the organisational boundary: the equity share and the control approach. Under the equity share approach, a company accounts for emissions from operations according to the share of equity in the operation. On the other hand, under the control approach a company accounts for 100 per cent of the greenhouse emissions from operations over which it has control. For companies who have complete ownership of operations the operational boundary will change little. However, where joint ownership is in place some variation in the calculated carbon footprint may occur (World Resource Institute & World Business Council for Sustainable Development 2008).

In a business such as a horticultural farm, scope one emissions are likely to include emission of nitrous oxide from fertiliser application or CO_2 emissions from fossil fuel powered vehicles. Furthermore, the organisational boundary is likely to exist at the property boundary unless the grower has a joint share in a retail organisation such as a farmers' cooperative.

Secondly, Scope two emissions relate to emissions produced in the generation of purchased electricity. While an organisation may account for scope two emissions, emissions physically occur at the facility where electricity is generated. The World Resource Institute and World Business Council for Sustainable Development (2008) recommend that companies should at a minimum separately account for and report on scopes one and two.

Finally, scope three emissions occur as a result of a company's activities in the wider economy. Products or services purchased by an organisation are usually accounted for under this scope. For example, the emissions resulting from the paid transportation of produce from a horticultural farm to market would be accounted for under scope three. While these emissions do not occur within the farm boundary, the grower can be considered indirectly responsible for the emissions resulting from the transportation of farm produce (Carbon trust 2008). Table 3 shows key scope one and three emission categories typically included in a crop based agricultural footprinting tool.

Table 3: Key scope one and three emission categories from an existing agricultural green house gas measurement tool

Scope one emissions categories	Mobile fuels	
	Stationary fuels Combustion	
	Fertiliser application	
	Soil emission (tillage practices)	
	Row cropping	
	Waste treatment	
Scope three emission categories	Packaging	
	Contract Machinery	
	Transportation / Freight	
	Purchased Products	
	Row Cropping	
	Scope 3 Waste Treatment	

Source: Provisor Pty & Yalumba Wine Company (2007)

The categorisation of emission sources in Table 3 is similar to more detailed work that has been carried out into energy efficiency reporting on a small number of horticulture production systems (Chen, Kupke & Baillie 2008). A comprehensive analysis of emissions in all three scopes for each stage of the life of a product (manufacture to disposal) is called a Life Cycle Assessment (LCA). Although few footprinting approaches include a full LCA assessment, a Publicly Available Specification (PAS) 2050 is currently being developed by Department for Environment, Food and Rural Affairs (Defra), the Carbon Trust and BSI British Standards that will measure embodied greenhouse gas emissions in any given product or service. PAS 2050 is due to be released in October 2008. Figure 1 provides an overview of the interrelationships of the different scopes the activities that generate direct and indirect emissions.

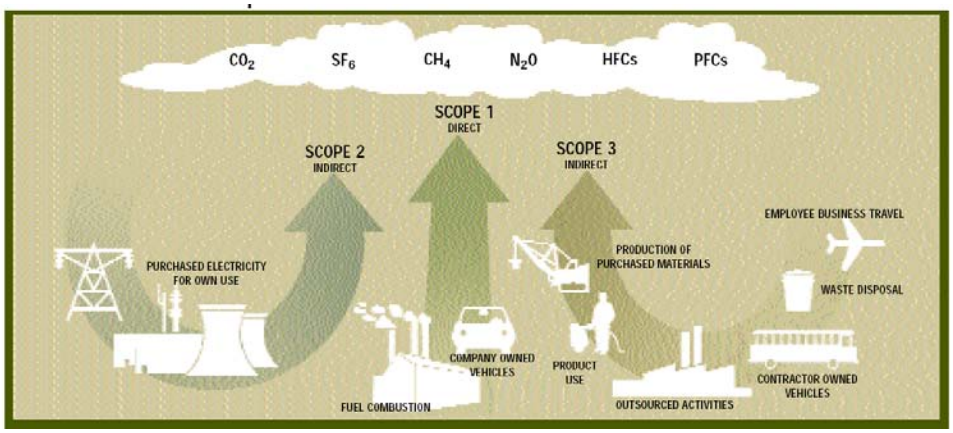

Figure 1: Overview of the interrelationships of the different scops the activities that generate direct and indirect emissions
Source: World Resource Institute & World Business Council for Sustainable Development (2008)

Lastly, a decision must be made regarding what "footprint" is actually being measured. While a significant amount of literature focuses on calculating the carbon footprint of a company or a business (Padgett et al. 2008; World Resource Institute & World Business Council for Sustainable Development 2008), it should be noted that scope of reporting is not limited to a business but can be expanded or contracted to focus on products, process or even whole countries.

5.0 The development of an international standard on greenhouse gas measurement

Due to a lack of internationally recognised best practice guidelines on greenhouse gas verification the International Organisation for Standardization (2006) has published a range of standards for greenhouse gas accounting titled ISO 14064. These standards provide unambiguous, verifiable requirements for the quantification, monitoring and verification of greenhouse gases. Standards Australia has since adopted these international standards through the Greenhouse Gas Measurement and Accounting Committee (Standards Australia n.d.). Similarly to publications such as World Resource Institute and World Business Council for Sustainable Development (2008) the international standards for greenhouse gas accounting and verification (International Organisation for Standardization 2006) include the greenhouse gases listed in the Kyoto protocol and use three scopes to account for direct and indirect emissions.

Thus, based on the discussion in previous sections, the definition adopted in this paper for a carbon footprint is:

> **A direct measure of greenhouse gas emissions (expressed in tonnes of CO_2) caused by a defined activity. At a minimum this measurement includes emissions resulting from activities within the control or ownership of the emitter and indirect emissions resulting from the use of purchased electricity.**

6.0 A general overview of the method for measuring a carbon footprint

Calculating a carbon footprint involves a number of steps. The first step is to clearly identify and articulate the purpose of the footprinting investigation. Clearly articulating purpose from the outset of a footprinting project will inform later methodological decisions such as the required level of accuracy and the acceptable margin for error.

The purpose and use of greenhouse gases measurement and measurement terms (such as a carbon footprint) varies greatly in the existing literature. At one extreme the term carbon footprint is frequently used in a marketing and communication context to promote to consumers products or services that help mitigate greenhouse gas emissions (MCI 2008). On the other hand, the term greenhouse gas accounting often associated with precisely measuring emissions from specific practices or processes for the purpose of informing the business decisions of the emitter. The calculation of companies' greenhouse gas emissions obligations under an emissions trading scheme is an example of such use (International Organisation for Standardization 2006). In between these two extremes is the measurement and labelling of the carbon footprint of different supermarket products to both inform consumer choices and reduce greenhouse gases associated with production and manufacture (Tesco 2007).

The second step is to clearly define the methodology that will be used for the measurement of direct and indirect emissions. The methodology will often depend on the purpose of the enquiry (step 1) and the availability of data and resources (Wiedmann & Minx 2007). There

are significant advantages to adopting an accepted methodological approach such as those outlined in publications such as International Organisation for Standardization (2006) and World Resource Institute and World Business Council for Sustainable Development (2008). While the level of detail contained in these publications may be in excess of the requirements of many organisations, adhering to the fundamental principles will significantly increase the accuracy and credibility of findings.

The third step in establishing the footprinting methodology involves clearly identifying the measurement boundaries by defining which emissions and over what timeframe they will be quantified. At this time the sources of emissions that will be classified as direct and indirect must be identified. Other issues such as emissions from leased equipment or wholly or partially owned subsidiaries also need to be resolved at this stage. The degree to which indirect and direct emissions are reported will largely depend on the purpose of the footprinting investigation established in step one.

The final step involves the calculation of the final carbon footprint based on collection of data on practices that result. While at a broad level much of this data may be readily available in the form of energy meters and fuel accounts, more detailed analysis may require the installation of specialist equipment. Assumptions, averages and estimates are often necessary to simplify the measurement processes.

An emission factor is a commonly used tool to estimate emissions based on the consumption of basic inputs such as energy, fuel or fertilisers. Emissions factors enable conversion from inputs to CO_2 equivalents and are widely used in estimating emission liability in an emissions trading scheme. For example, the National Greenhouse Gas Inventory Committee (2007) estimates that for every kilogram of nitrogen applied as fertiliser in horticultural production systems in Australia, 0.021 kilograms of nitrous oxide are emitted. Combining this emissions factor with the global warming potential of nitrous oxide means that emissions (in CO_2 equivalents) resulting from fertiliser application can be easily calculated providing that data on the use of fertilisers is available.

However, while emission factors are a valuable tool for simplifying the measurement requirements of calculating a carbon footprint, this simplification does reduce the accuracy of emission measurement which could have otherwise been achieved through detailed on site measurement. Furthermore, emissions factors can vary significantly from region to region and therefore a standardisation process is required. In Australia, emissions factors have been established by the Australian Government in publications such as Department of Climate Change (2008b). These emissions factors are used to calculate emissions from the Australian economy and establish the national emissions liability for the commencement of an emissions trading scheme in 2010.

Finally, during the data collection phase it is important to maintain measurement consistency so that the final carbon footprint figure can be related back to the nominated unit (time period, land area, person etc.). Furthermore, care must be taken to avoid under-counting and double accounting of emissions.

7.0 Conclusions and recommendations

A review of relevant literature has shown that the term “carbon footprint” has gained acceptance in the public domain without being clearly defined in the scientific community. Evolving from the ecological footprint concept, the term carbon footprint is now widely used as a “buzz word” to further stimulate consumers’ growing concern for issues related to climate change by describing anything from the narrowest to the widest interpretation of greenhouse gas measurement and reduction. The incorporation of this term into recent peer reviewed literature demonstrates the popularity of the term and its growing acceptance and use even within some scientific literature.

Although a universally accepted definition of a carbon footprint is yet to (and may never) exist, the general consensus of literature in the public domain is that a carbon footprint is concerned with the measurement of direct and indirect greenhouse gas emissions resulting from human based consumption and production practices. While there is no question of the popularity of this term, the suitability of this term for use in association with measuring greenhouse emissions in horticulture is more questionable.

In general, the term carbon footprint is associated with a less rigorous, consumer oriented, popularised concept of greenhouse gas reductions for the purpose of marketing the benefits of less emission intensive products and services. Alternatively, the term greenhouse gas accounting is generally associated with more rigorous measurement of greenhouse gases for the purpose of calculating and reducing a company’s greenhouse gases.
The plethora of definitions of carbon footprinting in the public domain is in contrast to the need to establish a clear an unambiguous definition of this term to inform methodological decisions associated with measuring and reporting on greenhouse gas emission. In this way, alternative terms such as “greenhouse gas accounting” while not having the public appeal of “carbon footprint” could be considered more suitable if a purely linguistic approach was taken.

However regardless of the term that is used, the development of a tool to measure the emission of greenhouse gases from horticultural systems must be based on national and preferably internationally accepted methodologies. International agreement on emissions reductions such as the Kyoto protocol (United Nations 1998) and international publications such as International Organisation for Standardization (2006) and World Resource Institute and World Business Council for Sustainable Development (2008) provide a valuable resource to inform these methodological decisions. Although the level of detail contained in these publications may be in excess of the requirements of many organisations, adhering to the fundamental principles will significantly increase the accuracy and credibility of findings.

At a minimum, a tool to measure and report on greenhouse gas emissions should consider emissions that result from practices directly controlled or owned by the unit (country, company, person, etc.) under study. However, significant scope exists for this measurement to be extended to include indirect emissions in the broader economy that result from an organisation’s management decisions. A measurement tool should also at a minimum, include the measurement of all six greenhouse gases covered in the Kyoto protocol expressed in greenhouse gas equivalents (United Nations 1998). Finally, clearly articulating the purpose of the footprinting study is critical to informing more detailed methodological decisions on the extent and approach to analysis that is required.

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