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An evidence-based assessment of online carbon calculators

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ABSTRACT

Online carbon footprint calculators have recently become a popular tool for educating the public about its climate impact. While calculators abound, no standards exist concerning how personal carbon footprints should be determined. As a result, prior studies have concluded that similar input assumptions can yield vastly different results depending on which calculator is used. Previous studies about carbon calculators have compared the modeling methodology used and the resulting footprint calculations. While providing useful insights, this approach does not leverage scholarly studies in order to create an objective yardstick for comparing the calculators. Prior studies also do not provide evidence-based prescriptions concerning how online carbon footprinting practice can be improved. To address the present situation, this study makes two contributions to the literature on carbon footprinting. First, the available evidence-base is synthesized in order to derive a set of 13 principles concerning how personal carbon footprints should be determined. Second, the same principles are used to objectively evaluate 15 commonly used carbon footprint calculators. The findings of the study indicate that carbon footprinting practice lags behind scholarly best-practice prescriptions. This creates an opportunity to use the research findings to improve current practice including driving standardization concerning how carbon footprints are determined.

1. Introduction

Over the past decade, there has been a proliferation of online "carbon calculators" providing individuals and households with tools for estimating their greenhouse gas footprints. These calculators are promoted by a wide variety of organizations including environmental NGOs, national and local government authorities, carbon offset providers, universities and energy companies.

The rise in the number of carbon calculators has occurred in tandem with the emerging consensus that climate change is anthropogenic in nature and that we need to act soon in order to prevent dangerous impact to humans and ecosystems (IPCC, 2007b, 2007c, 2007d). Failure to act is likely to bring about rising temperatures, increasing water shortages, declining agricultural productivity, more frequent extreme weather events and rising sea-levels to name a few of the likely consequences for continuing down our current business-as-usual path (see e.g. Brown, 2009; Hansen, 2009; IPCC, 2007a; Romm, 2007). In this context, carbon calculators constitute a potentially powerful bridge to connect individual action and lifestyle choices with the increasingly urgent need to prevent dangerous climate change. In fact, carbon calculators can be considered artifacts of a wider "individualization" movement within the environmental field, marked by a shift away from an exclusive focus on states and firms towards emphasizing individual responsibility (Paterson & Stripple, 2010).

While carbon calculators can play an important educational role in increasing public awareness, a key challenge at present is that there does not exist any standard or consensus regarding how personal carbon footprints should be calculated. As a result, calculators vary widely in terms of their structure as well as the results that are produced for similar input assumptions (Kenny & Gray, 2009; Murray & Dey, 2008; Padgett et al., 2008; Pandey et al., 2011). This might confuse users testing a selection of calculators and ending up with vastly different results. Using a comparison from a different field, imagine a user trying different online Body Mass Index (BMI) calculators, using the same input assumptions, and being told that his weight is underweight, normal, overweight and obese depending on which calculator is used. Such a situation could clearly contribute to a great deal of skepticism. Similarly, the present lack of consistency among online carbon footprint calculators could be counter-productive to efforts to engage the public in order to promote sustainable lifestyle and consumption choices.

This research makes two contributions towards addressing the present situation. First, literature is reviewed to derive a set of 13 normative, evidence-based calculation principles regarding how personal and household carbon footprints ought to be calculated. Second, 15 commonly used online carbon calculators are evaluated to assess the extent to which they conform to the identified evidence-based calculation principles.

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Table 1
Carbon footprint definitions.

Recent definitions
"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann & Minx, 2008, p. 4).
"A carbon footprint is equal to the greenhouse gas emissions generated by a person, organization or product" (Johnson, 2008, p. 1569).
"A measure of the total amount of CO_2 and CH_4 emissions of a defined population, system or activity considering all relevant sources, sinks and storage within the spatial and temporary boundary of the population, system or activity of interest. Calculated as CO_2e using the relevant 100-year global warming (GWP100)" (Wright et al., 2011, p. 69).
"Climate footprint: A measure of the total amount of CO_2, CH_4, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride emissions of a defined population, system or activity considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as CO2 equivalents using the relevant 100-year global warming potential" (Williams et al. 2012, p. 56).
"A measure of the amount of carbon dioxide released into the atmosphere by a single endeavour or by a company, household, or individual through day-to-day activities over a given period" (Collins English Dictionary, 2012).

This paper opens with a background section that defines carbon footprints and reviews prior studies focused explicitly on online carbon calculators. Next, the methodology is introduced with a focus on the approach used to synthesize the literature, the sampling process adopted for the calculators included in the study and the assessment framework. Following this, the synthesis of the carbon footprinting literature in presented in order to derive evidence-based calculation principles. The next section presents the empirical findings with a focus on comparing the sampled calculators to the evidence-based calculation principles derived from the literature. The final section discusses the findings from the study, provides guidance regarding possible future standardization of online carbon calculators and suggests avenues for further research.

1.1. Definition of carbon footprint

The term "carbon footprint" is a relative newcomer to the literature. In their review, Wright et al. (2011) conclude that the term appears to have been introduced for the first time around the year 2000 in public media. As the concept originated outside of the scholarly discourse, a wide variety of definitions have been proposed without any one gaining general acceptance to date. Table 1 above presents five recent definitions for carbon footprints.

From the above, this study adopts the following definition in light of the focus on carbon footprint calculations for individuals and households:

"A carbon footprint amounts to the greenhouse gas emissions generated by a person or household within a specified time period".

The author will return below to questions concerning which greenhouse gases should be included in the footprint and which global warming potential conversion factors should be used.

1.2. Prior studies about carbon calculators

To date, it does not appear that online carbon calculators have been the subject of extensive scholarly studies. In fact, the literature search only uncovered four prior studies in peer-reviewed journals that focused specifically on online carbon calculators.

Padgett et al. (2008) compared the output of 10 different US carbon calculators. When inputting the same assumptions, the author concluded that the results varied by several metric tons per person despite the calculators using seemingly similar calculation approaches.

Murray & Dey (2008) studied 11 web sites offering individuals and businesses to become "carbon neutral" based on online calculation tools. The author concluded that all 11 calculators requested input assumptions in different formats and that the estimated greenhouse gas emissions ranged from 6 to 11 tons per capita between the different calculators.

Kenny & Gray (2009) conducted a study similar to the above but focused on the output from 6 different international calculators based on Irish input data. The author concluded that results varied by as much as 5 tons per capita per year.

Pandey et al. (2011) included a section comparing online carbon calculators in their overall discussion of the definition of carbon footprints.

Taken together, the above articles convincingly demonstrate that there are no agreed standards regarding the computation of personal carbon footprints. Furthermore, it is evident that users are likely to get very different results depending on which calculator they choose.

1.3. Knowledge gap

It is interesting to note that the above four studies took their starting point in the calculators themselves. The studies compared which variables were modeled by the calculators and subsequently compared differences in resulting carbon footprints. While this approach has clearly yielded valuable results, the methodology has three main shortcomings. First, given that the starting point is the calculators, the approach is less likely to consider potentially important variables, or calculation logic, not reflected among any of the sampled calculators. This amounts to a form of "white space risk" as a comparison of existing calculators naturally only considers features included in the sample. Second, it appears quite possible that relevant research findings have not been implemented in the sampled calculators given that no standards exist. Hence, an exclusive focus on the calculators themselves may leave a blind eye to potentially relevant findings in the literature. Third, starting from the calculators appears to have encouraged an analysis of *what is* rather than *what ought to be*. That is, prior studies have a predominantly empirical character without a strong normative focus.

1.4. Research focus

In comparison to the above four articles, the present study instead takes its starting point in the academic and grey literatures concerning carbon footprints in order to derive a set of evidence-based carbon footprinting calculation principles. This approach is normative as it seeks to derive best-practice prescriptions independent of the current state of online carbon calculators. This is a logical next step of inquiry given that the carbon footprinting literature has reached sufficient maturity to make a comprehensive synthesis possible and meaningful. In addition, no such synthesis appears to have been undertaken as part of prior studies.

Following from the literature review, the evidence-based calculation principles are used to assess a selection of online calculators to determine the extent to which they conform to the calculation principles. This research design directly addresses the identified limitations of prior studies by conducting an assessment that is firmly grounded in the literature and provides normative guidance that can be leveraged to promote greater consistency regarding how carbon footprints are determined.

2. Methods

This Methods section consists of three parts. First, the process used to synthesize the academic evidence base to derive ideal