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Analysing the indicators and the associated recommendations of household emission calculators

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Abstract. Climate change and greenhouse gas emissions are some of the most noted topics of the last years. Carbon footprint calculators provide an interesting solution when it comes to informing people about the above topic. These calculators try to estimate the carbon footprint, the total amount of greenhouse gas emissions, based on information provided by the user that is related to various activities that may result in creating emissions. Some of the calculators also provide recommendations to the users, based on their results, in order to reduce their carbon emissions. This study provides a comparative analysis of the indicators used for calculating carbon footprint in available household calculators, as well as the recommendations provided for the users to reduce their footprint. The goal of this paper is to present the current state of household carbon footprint calculators regarding the data they require from their users in order for them to calculate their carbon footprint and any recommendation they may provide based on the results. This is achieved by analyzing a list of carbon footprint calculators that are freely available online and, specifically, the domains and indicators each calculator uses, along with the associated resulting recommendations.
Keywords: Carbon Footprint Calculators, Climate Change, Carbon Offset

1. Introduction

Climate change and the need for action to address it have been extensively studied in literature (Romm, 2018; Archer & Rahmstorf, 2012). The phenomenon is strongly associated with CO2 emissions (Hao, Chen, Wei & Li, 2016; Romm, 2018), impacting the environment in various ways (McCarthy, Best & Betts, 2010; Vousdoukas et al., 2017; Barros et al., 2012)

Scientific consensus supports the view that human activities significantly influence climate change, as natural causes cannot account for the observed changes (Shi et al., 2015). Greenhouse gas (GHG) emissions, defined by the UNFCCC's Kyoto Protocol (2008), generated by human activity play a crucial role in disrupting the natural balance (Yue & Gao, 2018). These emissions have already contributed to a temperature increase of 1.0 °C compared to pre-industrial levels, with projections estimating a rise to 1.5 °C by 2052 (IPCC, 2018).

To address climate change, the scientific community must propose solutions that help individuals, organizations, countries, and enterprises improve their actions to reduce their impact on the environment. Carbon footprint calculators are technological tools that provide insights into the environmental impacts of everyday activities and consumption (Salo, Mattinen-Yuryev & Nissinen, 2019). These calculators measure CO2 emissions and can be customized based on different methodologies and contexts. This study evaluates the characteristics of household digital carbon footprint calculators, comparing various online calculators and exploring their functionality and recommendations for reducing carbon footprints.

2. Theoretical Background

Carbon footprint calculators have evolved in recent years to incorporate multiple factors. These calculators enable individuals to estimate their own carbon footprint and make informed choices to mitigate their impact (Lin, 2016). Such self-assessment can enhance users' eco-guilt and promote the adoption of environmentally friendly behaviors, benefiting both individuals and collectives engaged in reparation actions (Mallett, Melchiori & Strickroth, 2013; Ferguson & Branscombe, 2010).

Carbon footprint calculators commonly assess aspects such as energy consumption, transportation, food, household facilities, water usage, consumed commodities, and consumer behavior (Dreijerink & Paradies, 2020). Calculation methods estimate annual greenhouse gas emissions for individuals, but results may vary, especially during holiday seasons when consumption increases (Brinkmann, 2021). The calculators use either manually entered or automatically calculated data, including user details like demographics or location. As users may lack expertise in carbon footprint analysis, user-friendliness, interactive design, and well-documented information are important considerations in the literature (Mattinen & Nissinen, 2011; West et al., 2015).

An important challenge is the need to for the calculators to be be frequently used by the users (Salo, Mattinen-Yuryev & Nissinen, 2019), since this has shown to affect the willingness to improve their carbon emissions behavior (Lin, 2016). Another challenge is the need for standardization and consistency among carbon footprint calculators (Padgett et al., 2008; Birnik, 2013). Moreover, there is a lack of recommendation regarding the carbon footprint reduction and that could affect awareness raising as well as the reliability of the calculators (Alves et al., 2020).

3. Methodology

The methodology of this study is comprised of three steps. **Step 1** of the methodology consisted of an analysis of the theoretical background regarding carbon footprint calculators. **Step 2** revolved around selecting the calculators that were to be analysed. The tool that was used was the Google search engine. The criteria of selection was that the calculator had to be available online and for free, as well as provide the carbon footprint for households. In **Step 3** the selected calculators were analysed. The focus of the analysis was the aspects that the calculators examined and any recommendations that were provided in order to reduce the carbon footprint of the user.

4. Results

The objective of this analysis is to identify the aspects that are examined in carbon footprint calculators, along with any recommendations that are provided with the purpose to help the user reduce their carbon footprint. Calculators primarily use questions regarding the users' habits for the calculation of their carbon footprint, but there can be values that are automatically set based on user selections, such as their location. Moreover, web forms are the preferred format for collecting user input. The aspects identified by the calculators are Introductory questions, Travel and Transportation, Home, Food, Shopping and Waste related aspects.

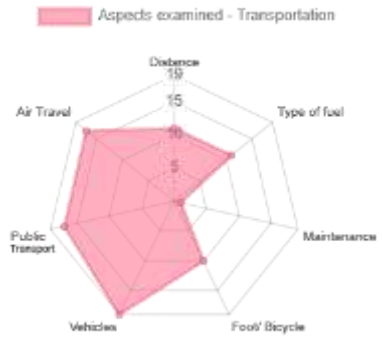

Figure 1: Aspects examined - Transportation

The introductory questions differ based on the level detail, containing questions regarding income, the location and the household members. The first aspect examined is the transportation habits of the users. This category focuses on the most frequently mentioned modes include personal vehicles, public transportation (buses, trains, etc.), airplanes, bicycles, or walking.The aspect of housing presents a wide range of questions regarding fuel consumption, energy efficiency, appliances, and insulation within the house. Regarding food consumption some calculators consider users' dietary preferences, food waste and locally produced food. Most of them prioritize assessing the balance between meat-based and vegetarian/vegan diets.

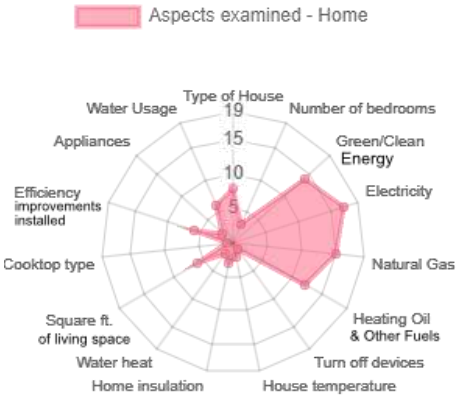

Figure 2: Aspects examined - Transportation

This focus stems from evidence indicating that meat-based diets contribute to increased greenhouse gas emissions (Farchi et al., 2017; Chapman et al., 2018). The next aspect focuses on tracking users' general consumption habits, which vary across different calculators. The most commonly assessed habits include purchasing clothes, general goods and appliances such as furniture, gadgets, and electric devices, as well as hygiene and beauty products.The final aspect pertains to waste generation and recycling habits of the users. It is fitting to include this category as the literature emphasizes the importance of reducing carbon footprint emissions associated with waste (Malakahmad et al., 2017).

Figure 3: Aspects examined - Food

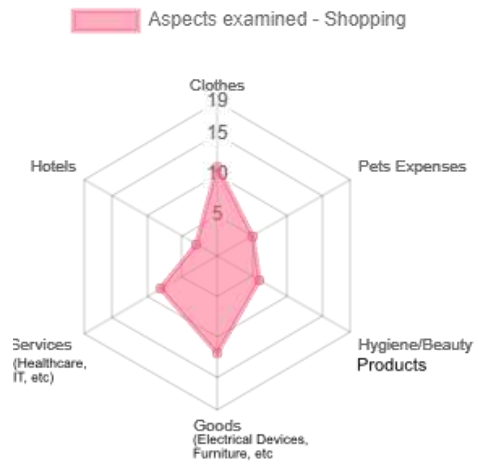

Figure 4: Aspects examined - Shopping

Offsetting the users' carbon footprint is also crucial, as it raises awareness about their contributions to carbon emissions and provides an opportunity to reduce their environmental impact. Offset methods suggested by calculators typically focus on travel, transportation, housing, and shopping aspects. Moreover, some calculators provided advice on how the user can reduce their carbon footprint based on their current habits. This advice was usually categorised into each of the calculator's aspects.

5. Discussion

The results over the examined aspects of the household carbon footprint calculators aim to improve their utility and standardization.

Based on the analysis of this study, the aspects that should be examined in carbon footprint calculators should be the ones related to housing, transportation, dietary habits, shopping, and waste management. An important observation is that the aspect of waste management was underutilised, with more than half of the analysed calculators not including questions regarding recycling or composting. However, waste management as an aspect is crucial for citizens to understand the importance of a circular economy.

Regarding the results of the calculators, two important features that should be present are offestting options and recommendations regarding the reduce of one's carbon footprint. While a lot of the calculators that were examined provide information regarding offsetting, not many offer actual recommendations based on the results of the user. These two features may look similar, their end result can be different, since offsetting does not necessarily affects the user's habits and consumption. Recommendations, on the other hand, focus on helping the user change their habits towards a more environmentally sustainable lifestyle.

6. Conslusions

Carbon footprint calculators play a vital role in empowering users to reduce their environmental impact and embrace sustainable practices. This study analysed 19 household carbon footprint calculators and identified valuable insights for the forthcoming advancement of the calculators.

One of this study's limitations is that only household calculators are examined, leaving the prospect of examining other types of calculators, such as ones that target businesses and products, for future work. Furthermore, only calculators that are free and online were analysed. Finally, the process of the calculation itself was not part of the study.

This study provided insights on what aspects are examined in household carbon footprint calculators that are available freely online, and proposed what aspects should be included in the calculators. Furthermore, it suggested two important features that should be present in the results of the calculators. Future research and development of carbon footprint calculators could benefit from this study, since it attempts to improve the standardisation utility of the calculators.

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Appendix: The carbon footprint calculators that were analysed

	Organization	Country/ scale	URL
1	The Nature Conservancy	USA	https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/
2	United States Environmental Protection Agency	USA	https://www3.epa.gov/carbon-footprint-calculator/
3	WWF	UK	https://footprint.wwf.org.uk/
4	Carbon Independent	UK	https://www.carbonindependent.org/
5	EPAM Systems, Inc.	Global	https://carbon.epam.com/
6	Conservation International	Global	https://www.conservation.org/carbon-footprint-calculator#/
7	Carbon Footprint Ltd	Global	https://www.carbonfootprint.com/calculator.aspx
8	myclimate	Europe	https://co2.myclimate.org/en/footprint_calculators/new
9	Selectra	Global	https://climate.selectra.com/
10	Carbon Footprint OBSERVATORY	Global	https://huellaco2.org/en/tuhuella.php#formularioContainer
11	Henkel	Global	https://footprintcalculator.henkel.com/en
12	PSLifestyle	Global	https://pslifestyle-app.net/
13	Ecowalla	Global	https://app.aurorasustainability.com/quiz/pre-1
14	Terra Pass	Global	https://calculator.terrapass.com/#/individual/home/default
15	Arbor Day	Global	https://www.arborday.org/carbon/calculate-household.cfm
16	Climate Hero Carbon Calculator	Global	https://carbon-calculator.climatehero.me/?source=MicrosoftAds&msclkid=7a23a0dba6e117a6deedc2106c08c82b
17	Wren	Global	https://www.wren.co/intro/lifestyle
18	My Carbon Footprint	Global	https://my.carbon.click/RM-CARBONCLICK/calculator
19	Global Footprint Network	Global	https://www.footprintnetwork.org/