INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED11
15 - 18 AUGUST 2011, TECHNICAL UNIVERSITY OF DENMARK

REQUIREMENTS OF A CARBON FOOTPRINTING TOOL FOR DESIGNERS

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ABSTRACT

This paper present the outcomes so far of a project to develop ‘co2ncept’, a carbon footprinting tool for product design concepts. It is clear that in order to be successful and useful to designers the tool must meet certain critical criteria These criteria, including level of detail, language, assessment, information, visualisation, education, strategy, detail, user experience and interface are discussed. The project has already faced a number of challenges, including assumptions and boundaries, making carbon meaningful and sharing data. These are discussed. The paper concludes that the resulting carbon footprinting tool will need to assess the carbon footprint of a concept in a quantitatively accurate manner, allowing key aspects to be identified, hot-spots to be explored and provide strategic recommendations for improvement. It will serve as a quick assessment tool, but also as a communication and educational channel for environmental sustainability. It will help designers to identify opportunities while also creating awareness of the environmental impact of their decisions.

Keywords: Carbon footprinting, New Product Development, Designers

1 INTRODUCTION

This paper discusses a research project aimed to investigate the use of an abridged carbon footprinting methodology to allow designers to calculate the carbon footprint of product design concepts. These concepts are not yet sufficiently developed to be assessed via traditional carbon footprinting methods. The developed resource will be aimed at designers involved in New Product Development (NPD).

Nowadays, global climate change is one of the main challenges facing society, politicians, industry and the economy [1]. Externalities such as carbon dioxide emissions are fast becoming material, meaning that investors consider them central to a firm’s performance [2].

Currently carbon footprinting methodologies, including the recent British standard on Carbon Footprinting PAS2050 [3], rely on the existence of a tangible product within a defined supply chain. A front end carbon footprinting methodology will make it possible for carbon footprinting to be carried out before a product is made. This will allow comparisons to be made between concepts, impacts to be identified, and improvement options considered at a stage where they can be addressed quickly and at considerably lower financial cost. This will enable designers to be more aware of the consequences of their design decisions.

This tool will be the first of its kind and has the potential to answer a need that has not yet been catered for by existing carbon footprinting methods. Firstly existing carbon footprinting methods require organisations to calculate the greenhouse gas emissions of their activities, from the direct use of fossil fuels to indirect impacts such as employee travel or emissions from other organisations up and down the supply chain [4]. This calculation requires exact data to be collected (e.g. from electricity bills). Designers involved in concept development, do not have exact data of this nature as, they are dealing with product *concepts* not defined products. They will have missing data regarding for example who the final material suppliers will be or what the distribution logistics will be, which precludes them from using traditional carbon footprinting methods.

A front end carbon footprinting tool will address this gap in the market. It will be the first tool to allow designers to calculate an abridged carbon footprint for product concepts. This will be done through the use of standard CO_2 and CO_2e conversion factors. Providing this function will allow designers to make more considered decisions at the early stages of the product development process with regards to concept selection, at a time where changes are neither costly nor time consuming. Hallstedt et al agree stating that the early part of the innovation process is a critical intervention point for the transformation of society towards sustainability [5].

Secondly, existing carbon footprinting methods are time consuming, because of the level of detail that they need to go into. This methodology will be designed to fit within the short time scale of the concept development stage of the product development process.

Current ecodesign theory supports the belief that designers have a valuable role to play in ecodesign because of their positioning at the early stages of the product development process (PDP), where the design brief is most flexible and the most critical decisions with respect to; cost, appearance, materials selection, innovation, performance, environmental impact, and perceptions of quality (longevity, durability, reparability), are made [6,7]. Lofthouse argued that industrial designers have a very similar role to play in ecodesign as they do in regular design, which means that (with or without the environmental focus) core industrial designers are concerned with:

- generating ideas and developing design concepts;
- adding to the scope of projects;
- developing concepts that are fit for purpose, pleasurable and easy to use; and
- using manufacturing and materials knowledge to design product concepts that are efficient and profitable to produce [8].

It has been demonstrated that this role lies at the operational end of ecodesign, where they 'translate product ideas into concrete ideas' [7]. The 'operational' end is a vital area to support, because of the high percentage of time spent focusing on these types of issues. Product development timescales are getting shorter and shorter, and the burden and requirement for evidence early on in the development process in order to support key development decisions is increasing. In addition to this, it is recognised that providing industrial designers with the ability to be able to implement ecodesign at the operational stage will vastly improve the likelihood of ecodesign products making it onto the market (*op cit*). A front end carbon footprinting methodology aims to support this theory.

The limitations of LCA of any kind is that it requires a product to have been developed before it can be assessed [9]. Carbon is increasingly becoming a hot topic within government and business because it allows a tangible comparison between things which couldn't previously be compared. This is reflected in the British Standard Institutes recent *Specification for the Assessment of the life cycle greenhouse gas emissions of good and services*, which uses carbon footprinting measures [10], and the move to carbon reporting by WRAP in their Courtauld Commitment [11].

This paper discusses the development of a framework for 'Co$_2$ncept', a front end carbon footprinting methodology. It outlines the design requirements for the tool and discusses the challenges faced so far.

2 DEVELOPING A FRAMEWORK

In order to understand the requirements of a front end carbon footprinting tool, a series of workshops were conducted with practicing designers. The aim of the workshops was to find what the user really wanted and expected from the footprinting tool.

The first exercise consisted on showing the designers a series of eco-design tools and getting their feedback from each one of them. Each tool was presented on a set of cards presenting key facts about the tool (see Figure 1). Six tools were shortlisted as a sample of the variety of options that are available. Each tool differentiated from the others depending on their cost, level of difficulty, time required to carry out the assessment, input data required from the user, user interface and a variety of deliverables.

Figure 1. Key facts about selected tools presented as a set of cards

Some of the shortlisted tools are online and free and others are a software application that has to be purchased and requires installation. Some tools can be filled in within a few minutes, while others can take up to several months in order to complete an assessment. Some tools show results in various charts, while others do not show any quantifiable results at all. Some tools are designed specifically for designers while others are targeted to a technical and specialised audience.

The second exercise asked the designers to give describe desired tool characteristics under the following headings:

platform,
level of detail,
language,
assessment,
information,
visualisation,
education,
strategy,
detail,
user experience and interface,
what else other than carbon, results, and
'what I don't want'.

The driver behind this activity was to build a picture of what designer's wanted the tool to look like and what information and levels of detail it should contain.

In the third exercise the designers were asked to describe or draw how they visualised their perfect tool (see Figure 2). This was a lighter activity developed to elicit each designer's opinions in a more creative manner.

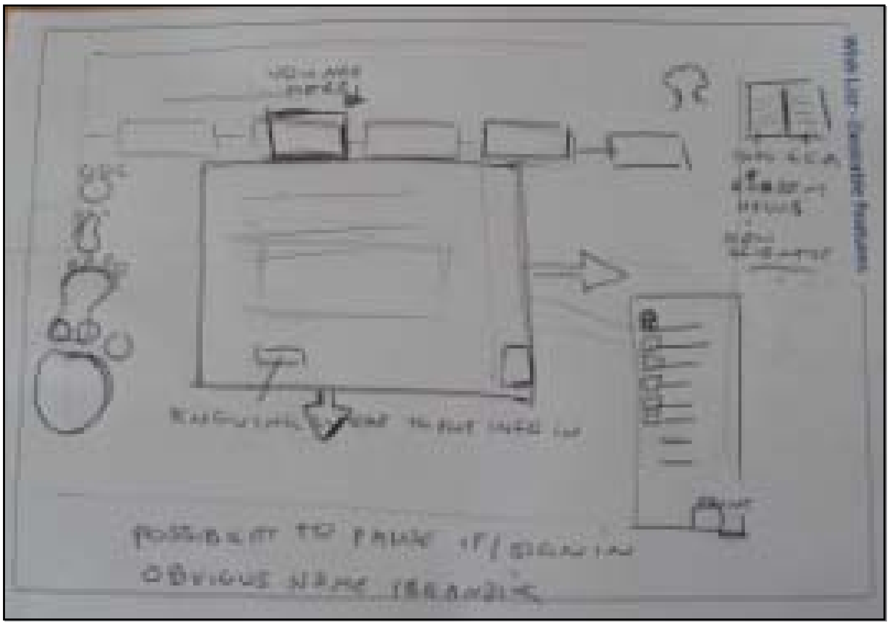

Figure 2. One designer's visualisation of 'the perfect tool'

2.1 Outcomes from the user testing workshops

The user testing workshops highlighted a number of desirable features for the front end carbon footprinting tool. These are outlined below.

2.1.1 Platform

There was a unanimous agreement that having the tool online would be the best option as it can be accessed everywhere. Even the idea of having a mobile version for smartphones and the ipad was considered useful. By having a personal / company account the user can access previous assessments, save and retrieve incomplete assessments and consult their assessment history. Designers wanted access to a company portfolio within which the user can see what has been done in the past, have the ability to learn from previous projects and compare progress. Designers also saw merit in being able to give their clients a personal log in, through which they can access and review the current selection of concepts.

2.1.2 User experience and interface

The tool must be visually easily to grasp and intuitive. An image as reference to the concept has to be always visible throughout each page, while the layout and toolbar has to be logically arranged and kept continuous throughout the navigation.

The designers wanted the tool to have an interactive, bold, simple, clean and fun interface where they can drag and drop elements, choose relevant options from a drop down menu, use colour coding in the navigation, upload images at any time as references have as many meaningful visual elements as possible. The tool must clearly show the progress status of their analysis of the products carbon footprint and clearly indicate the user’s current position within it. The user should be able to jump freely from one stage to another and the tool has to be flexible enough to be customized depending on the user’s preferences. The user should be able to compare more than one concept simultaneously and have the ability to amend results at any time. An intuitive, colour coded presentation of results is a must and all outputs should be available in a report format and should be able to be printed out, send by email or saved as a PDF.

2.1.3 Level of detail
Designers discussed the possibility of different entry levels depending on the design concept and the user's level of expertise. The basic level should be able to support concepts that are hand sketched and in the advanced level the user should be able to import their 3D CAD model and assign materials directly in the tool. All of the entry data should be available within the tool, for example designers highlighted the desire for a material library where an overview description and an image for each material is provided, including most common manufacturing processes, an overview to its carbon footprint value and general applications. In addition, having a search engine where a material can be found by property, by low carbon options or by choosing from a list of application images was desired. The tool should be able to calculate automatically the carbon footprint of a part by getting the weight from its material and volume; this would allow easy calculation of weight from designer's sketchwork.

2.1.4 Assessment
For designers time is crucial at this stage for this reason designers insisted that the assessment should not take longer than 10 minutes, at the same time that it delivers meaningful and useful results. Designers also discussed the desire for the assessment to be carried out within one main page.

The tolerances and margins of error must be stated clearly when showing the results of the carbon footprinting analysis. The tool should be able to provide different levels of output and the user should be able to turn on and off as many layers of information as they want at any time or simply tick boxes to customize the amount and detail of output data.

2.1.5 Strategy
The key elements within the carbon footprint should be highlighted with a complementary list of suggestions on how to improve them and what to do next. Designers also requested content showing possible scenarios with information about the impacts of their decisions in a real world context.
They also desired a support section where they could access a glossary of technical terms, material specifications, find links to external sites where they can find further information about sustainability, life cycle assessments, and other appropriate information and inspiration. Some designers would like to see what is happening at a policy level and what legislations they have to comply with.

2.1.6 Information
Designers did not want the tool to be daunting, boring, complex, confusing, or dull. They disliked the thought of being overwhelmed by large amounts of information. Furthermore, they did not want the tool to focus only on the negative aspects and to make them feel guilty or scared.

2.1.7 Value
Finally designers said that they have to know that carbon footprinting can bring some value to them. The value can come from the client's brief, to have a 'headstart', to achieve a 'feel-good' feeling or to receive any sort of incentive for doing it.

2.3 Database development
Calculating the carbon footprint of product design concepts will require the use of standard carbon databases as suppliers, supply chains and distribution channels will not yet have been specified.

The initial brief for the research project included the selection of an appropriate database to use within the carbon footprinting tool. The 18month project and only 1 research meant it was not feasible (or deemed necessary) to develop our own database, however, a search of existing databases early on in the project highlight a number of issue.

- No database held a complete set of materials and processes.
- All the databases were calculated in different ways.
- Some databases only calculated CO_2 footprints, whereas others included CO_2e calculations.
- Different databases made different lifecycle assumptions when calculated the carbon footprint.

Some databases used product categories to calculate different types of products in different ways, making comparisons between types of product impossible.

There is currently an international drive towards an agreed database for carbon footprinting due to the growing concern that there is no scientifically substantiated, consistent and internationally harmonized convention for defining how a CO2 footprint is to be measured [1]. Recent advances in this area, with the publication of PAS2050, are a step in the right direction, however the flexibility allowed within the methodology still negates the ability for accurate comparison between products.

2.2 The need to move beyond carbon

It is well known that sometimes by reducing the carbon footprint of a product there might be negative effects on other environmental categories [1]. When assessing the CO2e impact of concepts designers tend to focus more on material choice and impact as opposed to considering the whole life impacts of their design [12]. Although building upon a life cycle approach, carbon footprints address only impacts on climate change. When exclusively carbon footprint data are used, other important environmental impacts are neglected while often running opposite to climate change, which can result in a 'shifting of burdens' [13].

The Product Carbon Footprint (PFC) Pilot is a German project developed in 2009, where a group of specialists in the subject calculated the carbon footprint of 15 products from 10 different companies. In their case studies, they examined other environmental criteria in addition to the CO2 footprint. By including other environmental factors it was possible for them to estimate the relevance of greenhouse gas emissions as an individual factor compared to other types of environmental impact. Such a comparison also shown whether reducing the greenhouse gas emissions of a product might negatively affect other environmental categories. A comprehensive sustainability assessment of products cannot be carried out on the basis of the PCF alone. Nevertheless, the PCF is a fundamental indicator for some products or product groups [1].

Feedback from designers suggested that they would like the option to see other impacts alongside a products carbon footprint, but again would need guidance to interpret results and guide decisions where there were conflicting results. Other environmental factors include embedded water, the use of potentially scarce or insecure resources, the landscape and biodiversity impacts of resource extraction, production of goods and their eventual wastes [14]. Others would be: Eutrophication, land use, energy and raw material consumption, toxicity, acidification of soil and water, and embodied energy [15].

3 CHALLENGES

The project has already faced a number of challenges, including assumptions and boundaries, making carbon meaningful and sharing data. These are discussed below.

3.1 Assumptions and boundaries

To calculate the product carbon footprint correctly, the entire life cycle of a product must be taken into consideration [1] (see Figure 3). It is of little use to create an assessment tool focusing on only one point in the life cycle of products if the solutions generated problems elsewhere in the rest of the supply chain [16].

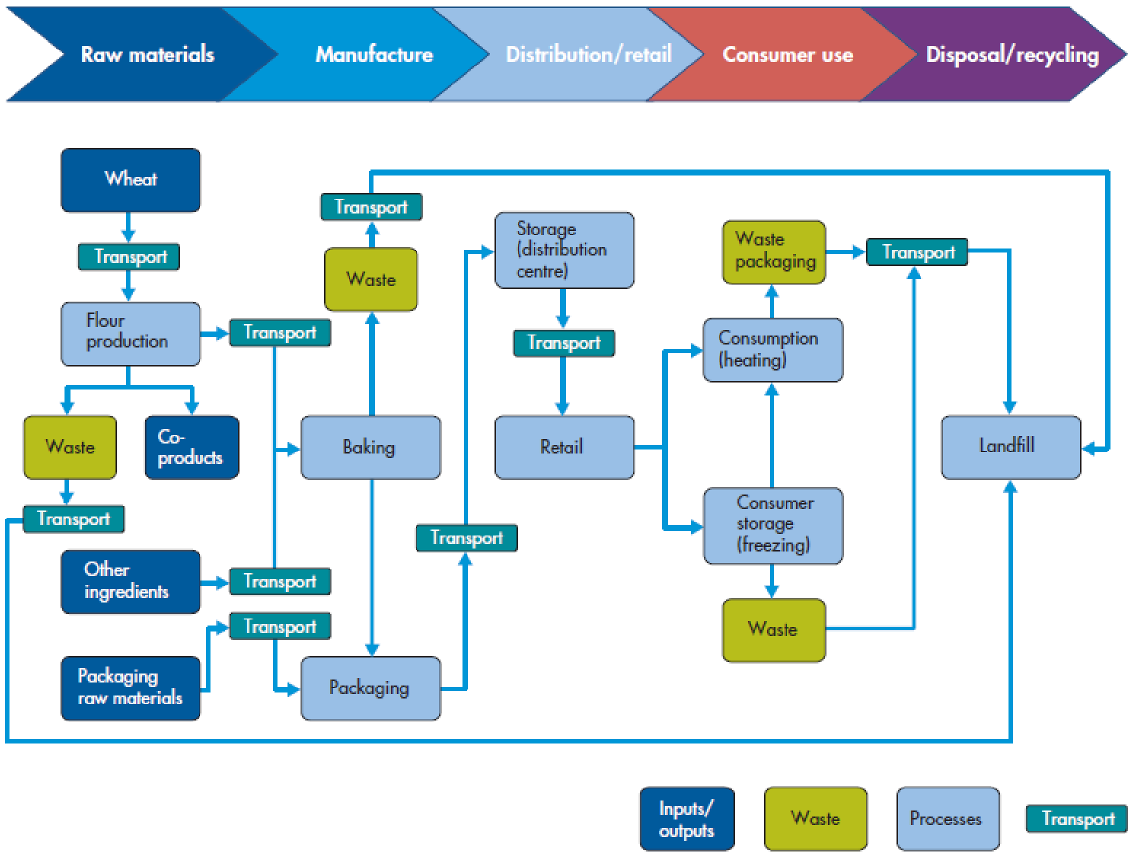

Figure 3. Calculation stages [17]

The Co_2ncept tool will assess the carbon footprint of design concepts where much of this data will be unknown at the point of concept generation. Therefore the tool will present a consistent and accurate method of accounting for the carbon footprint of core product only. This tool will not take into account decisions that are taken further down the developmental chain in regards to, for example, suppliers, supply chains, location of manufacturers, and many other decisions that can greatly affect the overall impact of the product. However it will allow designers to make decisions early on in the design process based on environmental impact. The early stages of the product innovation process are critical in defining the core characteristics a product will have once it is out in the market. Sustainability aspects should play a major role in the concept phase to stimulate creativity in concept generation and to guide evaluation, thereby finding early indications of negative impacts on ecological systems that product concepts might cause throughout their life cycle [5]. Quality, functionality and production costs are important things that product designers take into account during their design process, however, nowadays other environmental factors are gaining equal importance. According to a recent article in *Harvard Business Review* sustainability has become an essential business strategy and the key driver of innovation [18].

It is envisaged that the methodology may need to take into account data based on set assumptions, and that these set assumptions may need to change dependent on product category. These assumptions may include; functional unit, distribution, shopping tour, consumer use, consumables, and disposal.

3.2 Making carbon meaningful

Carbon footprinting does not only measure carbon dioxide. More accurately it is Co2e footprinting, taking into account, alongside carbon dioxide; methane, nitrous oxide, hydroflurocarbons, perfluorocarbons, and sulphur hexafluoride. Each of these green house gases (GHG's) has it's own global warming potential (GWP), the heat traping potential power over 100 years. This is measured relevant to Co2 (see Table 1 for the GWP of all 6 GHG's).

Table 1. The GWP of 6 GHG's (UNFCC), with key producers (DECC) [19]

Green house gas	Global warming potential	Key producers
Carbon dioxide	1	Fossil fuel combustion, land clearing, cement production.
Methane	21	Livestock, extraction of fossil fuels, rice cultivation, landfill, sewage
Nitrous Oxide	310	Industrial processes, fertilizer use
Hydrofluorocarbons	140-11,700	Fridges, aerosols, air conditioners
Perfluorocarbons	6500-9200	Aluminium production, semiconductor industry
Sulphur hexafluoride	23,900	Electrical insulation, magnesium smelting

In the UK the key producers of GHG's are in energy supply (35%), transport (21%), industry and business (17.9%), and in residential homes (13.4%, [20] all of which are impacted by the production, distribution, use and disposal of consumer products.

The Committee on Climate Change (CCC) says a GHG reduction of 1.7% a year is required from 2007 to 2020 in order to hit targets, or a 2 tonne drop per person each decade before 2050 to meet targets, and this does not take into account any UK population rise. Table 2 shows the scale of the challenge.

Table 2. Carbon targets for 2020 and 2050 (Turner, 2009, [19])

Year	GHG annual emissions target (MtC02e)	GHG budget per person assuming no population growth (61.4 million people)	GHG budget per person assuming project population growth
2020	540	9	8 (65 million)
2050	160	2.6	2 (77 million)

An average consumption of 2tons per year is the same as 5.5kg per day [1]. But what do these numbers really mean? To put 5.5kg per day into perspective this is the equivalent of either: 5 1/2 loaves of bread; 4 bottles of wine; 2 baths; 2 loads of dried laundry; or 5 1/2 paperback books [21].

Designer's also find it hard to put carbon footprinting outcomes into perspective and therefore engage with carbon footprinting. Designer's discussed not knowing if the difference between two carbon footprints was marginal, or expansive, and thus found it hard to balance benefits against other issues such as cost and performance. It was also deemed to be a complex task to find out if the 'tolerance' on abridged carbon data negated the purported performance benefits of alternatives.

The language used in a number of the carbon footprinting tools discussed, such as normalization, Monte Carlo analysis, Co2e, and allocation, was also not understood by a number of designer's and was felt to add to the complexity of carbon footprinting.

3.3 Sharing data

All designer's agreed on the necessity of being able to compare their design concepts against other internal and external products. They would also like to compare their products to 'best in class' products (e.g. WRAP, DEFRA, Okala), and also to input benchmarks to work towards or compare their products against.

However all designers highlighted the wish to see competitors products, but not to publish their own products within the public areas of the tool. Concerns about intellectual property, competitive advantage and commercial sensitivities were the drivers behind the secrecy. In new Product

Development maintaining confidentiality is critical and patent protection is no longer available if a design has been made public.

One method of sharing carbon footprinting data, without compromising commercial confidentialities, is to present carbon footprinting data as a consumer meaningful unit of measure [22]. Using this method product data is abstracted and presented as a single figure which represents the carbon footprint of the product. Another benefit of using a consumer meaningful unit of measure is its use to compare seemingly disparate concepts (for example from different product categories).

4 CONCLUSION

Designers working with NPD are well placed at the early stages of concept development to define the core characteristics of a product. These characteristics will include the impacts that the product will have on the environment. Therefore designers have the opportunity to minimise the negative environmental impacts of a product at this stage, where decisions are neither costly, nor time consuming.

In order to support this decision making process the development of ‘co2ncept’ a carbon footprinting tool for product design concepts is discussed. It is clear that in order to be successful, and useful to designers the tool must meet certain critical criteria.

To create awareness the results need to have a practical relevance to the user, be placed within contexts and be based on credible, comprehensive and transparent data. It might be that a result can be visualized and substituted in different ways depending on the user needs or level of knowledge. Co2ncept will need to assess the carbon footprint of a concept in a quantitatively accurate manner, allowing key aspects to be identified, hot-spots to be explored and provide strategic recommendations for improvement. It will serve as a quick assessment tool, but also as a communication and educational channel for environmental sustainability. Calculating the carbon footprint of product design concepts will help designers to identify impact reduction opportunities while also creating awareness of the environmental impact of their design decisions.

The communication of results and the language used throughout the user interaction must be relevant to the user’s level of knowledge and experience, in order to be easily comprehensible and useful. The tool needs to contain different entry levels where they can calculate the carbon footprint of a rough sketch, but also import data from a concept CAD model. The results will not be intended for communication to consumers, but as a mean of strategy and innovation guidance for designer working towards the production of low carbon products.

Co2ncept is aimed to be open source, to give credible results. Although it will be a quick and easy assessment tool it will be based on relevant policy (PAS2050, ISO 14040/44). It is hoped that companies will be able to share their results in a way that maintains confidentiality and protects commercial sensitivities, but that will allow the global community to benchmark best in class products in order to afford even greater overall sector improvements.

ACKNOWLEDGEMENTS

Thank you to the Engineering and Physical Sciences Research Council for funding this 18month project (ref EP/H022422). Thank you also to Boots and Pi3, the two collaborating companies for their help and involvement in this research.

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