Introducing Financial Data and Groups in a Carbon Calculator: Issues With Trust and Opportunities for Social Interaction

Aksel Biørn-Hansen
University of Gothenburg
Gothenburg, Sweden
aksel@biornhansen.no

Wolmet Barendregt
Eindhoven University of Technology
Eindhoven, The Netherlands
w.barendregt@tue.nl

David Andersson
University of Gothenburg
Gothenburg, Sweden
david.s.andersson@psy.gu.se

Abstract

A range of carbon footprint calculators have emerged over the years, aiming at promoting pro-environmental behaviour through providing information about what impact people have on the environment. Up until recently, most of these calculators have been focusing on providing feedback on an individual level. This paper presents an exploratory study of a new kind of carbon footprint calculator, which offers a social and collective dimension not found in many other existing calculators. This is done through the introduction of a group feature allowing people to engage with and compare themselves to each other. The calculator also makes use of real-time financial data in combination with user generated data in order to provide reliable and continuous estimates of a person's carbon footprint. Through an explorative study, in which we conducted two in-depth interviews with four participants, we have investigated the reactions to using the carbon calculator for the first time as well as after two to three weeks of unsupervised use. Our study indicates that the use of transaction data does not automatically lead to a higher trust in the calculated carbon footprint due to the numerous insecurities that are revealed. Registry data on the other hand seems to be appreciated because it eases the input that people have to provide anyway. While groups seem to be a promising feature, there is a need to investigate what information about people's carbon footprints should be shared as well as how the groups and the interaction with the carbon calculator can be kept lively and interesting over time.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**;

Keywords

carbon footprint, carbon calculator, mobile application, financial data, social dynamics, behaviour change

ACM Reference Format:
Aksel Biørn-Hansen, Wolmet Barendregt, and David Andersson. 2020. Introducing Financial Data and Groups in a Carbon Calculator: Issues With Trust and Opportunities for Social Interaction. In *7th International Conference on ICT for Sustainability (ICT4S2020), June 21–26, 2020, Bristol, United Kingdom.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3401335.3401662

ICT4S2020, June 21–26, 2020, Bristol, United Kingdom

ACM ISBN 978-1-4503-7595-5/20/06.
https://doi.org/10.1145/3401335.3401662

1 Introduction

Climate change is a pressing societal challenge, but despite the urgency to mitigate our environmental footprint, global greenhouse gas emissions are still rising [17]. To tackle this challenge, several attempts have been made over the years to create tools that can inform people about how their behaviour impacts the environment, from tools to visualise energy consumption in public spaces [12] to providing feedback about travel behaviour [9]. Carbon footprint calculators are one type of such a technology available today which seek to measure and give feedback on the carbon footprint of activities and/or the lifestyle choices of individuals. Typically, carbon footprint calculators (hereby only referred to as carbon calculators) offer ways for individuals to input data about their lives, such as details about their household or transportation habits, and get out information about what impact this has in terms of greenhouse gas emissions. Most modern carbon calculators today do this by reporting the annual impact on the environment by the user [21], but many new calculators also provide comparisons to national averages, tips and pledges as well as options for carbon offsetting [22]. Such features can be related back to intervention techniques from behavioural psychology, such as feedback, information provision, prompts, social comparison and commitment [10].

Although such features might be useful for many to understand their impact on the environment, they rest heavily on the assumption that if the user is provided with the right kind of decision support they will act more environmentally friendly. This assumption has been criticised, both because it relies on assumptions of rational agents [11, 15], and due to the lack of empirical support showing a strong relationship between awareness and willingness to act in climate friendly ways [13]. Carbon calculators have also been criticised for putting too much focus and responsibility on the individual [23, 24].

Despite the criticism, studies evaluating the effects of using carbon calculators are inconclusive. Some studies involving carbon calculators have for example reported actual reductions amongst their participants, [e.g., 1, 26]. However, a longitudinal study by [5] showed that participation in an experiment involving a carbon calculator significantly increased awareness, but did not result in any measurable reductions in energy use. One possible explanation for this failure is that "[s]ocial influence is a pervasive force in human social interaction. In many social encounters, individuals modify their opinions, attitudes, beliefs, or behaviour towards resembling more those of others they interact with" [8]. For this reason, the

effort of making individuals aware of their carbon footprint is likely to have little effect, unless there are ways to interact with others.

In this paper, we therefore take a closer look at people's use of and reactions towards a new carbon calculator called Svalna (meaning "to cool down", in Swedish). This carbon calculator was released in 2018 but is still being improved. Svalna employs transaction data from the users' bank statements, together with registry data (data about heating requirements based on the user's home address, and mileage, fuel consumption and type of fuel based on the user's car registry number) and data filled in by the users themselves to provide reliable and continuous estimates of users' consumption-related carbon footprint. This is a current trend in the area of carbon footprint calculators, with both start-ups and recently large corporate banks developing and releasing similar features or products [20]. However, another key feature of this carbon calculator is that users can form groups with, e.g., friends or colleagues at work, and see their combined emissions, compare themselves to each other and set a common goal. While there are several studies that have been conducted on carbon calculators in the past [1, 5, 22, 26], the use of transaction data and the social setting that the group feature creates is a rather unexplored area of carbon calculators [1]. With the results of this study we hope to contribute with insights about the potential and limitations of such a tool to create social change. The limited number of interviewees and the fact that Svalna's technology was not mature when the study was conducted, however mean that we can only provide tentative answers.

Figure 1: Screenshots of three main features of Svalna. On the left, an overview of the carbon footprint, in the middle, a drill-down of the emissions in different categories, and on the right, suggestions and goal setting for reducing emissions.

2 The carbon calculator

Svalna is a research-based company based in Gothenburg, Sweden. To estimate the carbon footprint of individuals, the company has developed a novel hybrid approach that makes use of financial transaction data from the user's bank statements paired with information from official registers and data entered by the user themselves. Combined, these data sources provide a rough but reliable estimate of the user's carbon footprint that is continuously updated with new consumption data (see [2] for a detailed account of methodology and design). The carbon calculator comes in the form of a mobile app.

When first using Svalna, the user is asked to create an account, decide whether to connect their bank account or not, as well as answer a series of questions concerning their transportation habits, housing, and diet. Those who do not choose to connect their bank account get an additional question about income and savings. Finishing the on-boarding process, the app provides the user with an overview and breakdown of their emissions in different charts, allows them to set a goal and to see how different changes to their lifestyle would impact their carbon footprint (see Figure 1), as well as offers them the option to create and be part of groups. It is worth noting that the version of the app available at the time of this study did not contain any information or educational material on how Svalna calculates emissions. For the scope of this paper and the sake of brevity, we will only explain how the Group feature works in more detail.

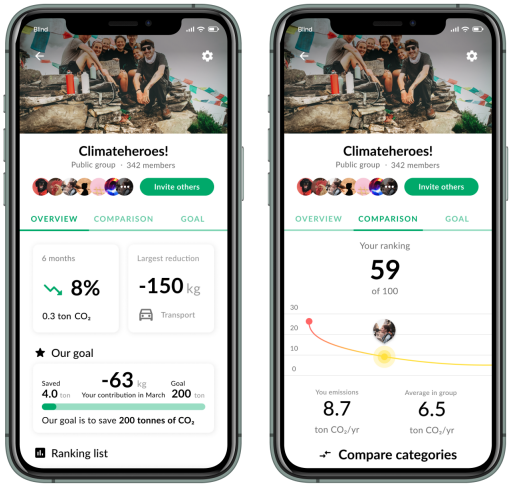

Figure 2: Screenshots of the group feature of Svalna. On the left, get an overview of the group and key metrics. On the right, users can compare themselves to the rest of the group.

The Groups feature in Svalna allows users to form and join groups where they are able to decide on a common goal, compare themselves to each other or set up a contest among sub-groups (see Figure 2). Groups can consist of, e.g., co-workers in a workplace, students in a class, people with a shared interest, groups on social media such as Facebook, or neighbours. Users residing in the same municipality are by default assigned to a municipality group. Groups can either be open or private. When a group is open, the overall trend of the group is visible to other users of the app and it is possible for strangers to make a request to join the group. Different groups can be used in different ways. Municipality-based groups, for example, offer a possibility for the local environmental administration to get in touch with already motivated citizens to inform them about current work and goals, and engage them in different events and activities.

The aim with the group feature is to increase the users' motivation to reduce their carbon footprint by evoking a sense of team spirit, while also implicitly activating a sense of competition or comparison to others in the group through a ranking graph and a graph comparing the user's average to the group average. As stated in the introduction, social influence is an important driver for behaviour change [8]. Research has shown that several motivational processes are triggered by allowing users to compare themselves to others, either by collaborating or competing [4, 25]. Comparative feedback that includes some form of social interaction has been shown to result in significant and durable behavioural change [25]. The strong norms around personal carbon footprints among users of Svalna are thus likely to affect users that are either above or below the average emissions [6, 7].

3 Research Approach

To investigate people's reactions to the calculation of their carbon footprint by using transaction data and their interest in joining a group, we performed an in-depth qualitative interview study. The study consisted of two parts. In the first part, the participants were introduced to Svalna and were asked to try out the app using a thinking aloud protocol [18], followed by a short interview. Both the introduction and interview were audio-recorded. Two to three weeks after the initial activity, we conducted semi-structured follow-up interviews with the participants in order to understand their experiences of Svalna after having had time to use it in an unsupervised manner. The interviews were based upon a script, and lasted each between 30-60 minutes. The questions in the interview concerned the participants' use of Svalna during the weeks up to the second interview, their thoughts about the different features in the app, as well as their thoughts about sustainable behaviour and social aspects related to this. The interviews were held either through Skype or by telephone. All follow-up interviews were also recorded, either with both audio and video recording (video conferencing) or only audio (phone).

Although we initially recruited seven people for this study, only four participants were able to participate in both the initial activity and the follow-up interview a few weeks later. Although it could be interesting to report on the data from all seven participants, we have chosen to focus on the results of those four participants who participated in both interviews for the sake of methodological clarity. All participants were employees at a municipally owned housing company in Uppsala, Sweden. However, they worked within different departments, such as procurement, human resources and building maintenance. They were of different ages (ranging from 27 to 60 years old), and gender (2 male and 2 female). The housing company is in the process of joining an internal campaign focusing on sustainability using Svalna. None of the participants had any previous experience with Svalna. We will refer to the participants as P1, P2, P3, and P4 (e.g., Participant one = P1) in this paper. See table 1 for an overview of the participants and key metrics of their use of Svalna during the study. To ensure the integrity of the participants taking part in this study, appropriate steps were taken, including asking for informed consent, informing the participants of their right to be anonymous, the way their data would be stored, as well as their right to abort any ongoing research activity in which they took part.

The analysis was conducted in stages using content analysis, which is a method for "sorting, synthesising and organising unstructured textual data" in order to identify common themes in the data [3]. Content analysis can be either inductive or deductive, with the former usually being preferred and more common [18]. In our case, the interviews were first transcribed using word processing software. The transcriptions were done in an edited format, meaning that word crutches and misstatements were omitted from the transcriptions [3]. We then coded two of the interview transcripts inductively, forming a set of codes, which was then used to analyse all the interviews again. All coded observations were thereafter synthesised in order to identify common themes in the data.

Table 1: Overview of the participants and their use of Svalna in the two weeks up until the interview

Participant	Previous experience using calculators	Bank connection	Usage of Svalna after introduction
P1	No	Yes	A few sessions, ca. 30 minutes in total
P2	Yes	Yes	Used only once, a few minutes in total
P3	No	Yes	A few short sessions trying it out
P4	No	No	Used only once, ca. 5-10 minutes

4 Results

In this section, we will present the results from our study, starting with the participants' general attitudes towards sustainable behaviour as well as their previous experiences with other carbon calculators. Thereafter, we will discuss their experiences of calculating their emissions using Svalna, their attitudes towards the use of groups in Svalna, and their opinions on the effects of using Svalna.

4.1 Attitudes and previous experience

All of the participants expressed an interest in sustainability and thought it was an important topic. They also said that they wanted to contribute to reducing emissions, with some participants less engaged than others. The interest in sustainability among the participants was reflected in what they did on a daily basis. The participants described a range of different actions they take in their everyday life, such as sorting their waste (P3), buying ecological products when grocery shopping (P3), and buying furniture second hand (P2). The motivations behind these actions were many, ranging from very practical and detailed to more general and all-encompassing motivations. For instance, P2 said that she does not have a car because it is expensive and that it is much easier to bike, while P3 said: *All means are good as long as it leads to a reduced climate footprint*, reflecting a "deeper" motive connected to reducing emissions overall.

Carbon calculators were something that most participants were not familiar with before being introduced to Svalna (P1, P3). As P1 said: *It has mostly been a lack of knowing that such tools exists. I try to the best of my ability live as wisely as possible, but I have not, until Svalna showed up, even known that such tools exist.*. Others, like P3, speculated that a reason for him not checking out other carbon calculators previously was that he always believed he was doing well concerning his environmental impact compared to others and did not feel a need to investigate it further. These thoughts were also clouded with a bad conscience for not looking into it earlier. One of the participants (P2) had tried out other carbon calculators previously, mostly being one-time occurrences and nothing that followed her over a longer period of time. The calculators that P2 had used were of the more static type in which she could answer a set of questions about her lifestyle or calculate the emissions from travelling.

4.2 Reactions to calculation of carbon footprint

During the first interview, the participants were asked what they thought about connecting their bank account to the app. Overall, the participants were positive about the idea because it would make the data input more efficient. P3 put it this way: *...I understand that it's important if you are going to be able to draw some reasonable conclusions about how my consumption affects my footprint. The alternative is that I fill in everything myself by hand....* That said, the concept of giving the app access to transaction data from their bank also gave rise to mixed feelings. One participant did not want to do it as she thought it was "too" serious, and another did not understand how this would be useful: *... why should I connect my bank? It's strange.* However, in the follow-up interview, three of the participants indicated that they had connected their bank to the app and had investigated their transactions and tried to re-categorise some of them. P4 was the only participant who had not connected her bank to the app, and said she had spent just a few minutes looking at the app together with colleagues. She expressed scepticism towards connecting her bank as she thought it felt risky, as well as feeling that the app was not so accessible: *We have examined the app and how it looks, and [thought] it was not so accessible somehow. They did not think so either. Another thing that I was a bit unsure of was connecting my bank. It felt a bit risky as it is a new app.*

The choice of connecting a bank account or not has consequences for how the carbon footprint is shown in the app. Without a connected bank account, the carbon footprint shown in the app is an estimated total of emissions divided into different consumption categories. This estimation is static and the user cannot investigate this further since it is not based on real transaction data. With a connected bank account, it is possible to drill down into the carbon footprint, look at smaller categories, review lists of transactions and their corresponding footprint as well as (re)categorise them. The former alternative, without a connection to separate data sources, is the most common method used to calculate people's carbon footprints. P4, the participant who chose not to connect her bank account displayed uncertainty about the truthfulness of the numbers provided. When asked if she understood her carbon footprint shown in the app, she said: *No, I don't really think so. I did not think it was correct or it did not feel like it was correct or I did not feel convinced that it was correct, but maybe it is....*

For the participants who did connect their bank account to Svalna, a calculation of their carbon footprint was made based on their purchases. However, our interviews showed that this approach also gave rise to doubt and scepticism about the numbers provided. P2 for instance said she had difficulties with transactions being wrongly categorised by the system, such as savings, resulting in a high carbon footprint. P2 also mentioned that the app often had chosen an incorrect category or subcategory for a transaction, and thought some of the decision the app had made about the categorisation were peculiar. P3 thought it was a bit hard to understand or relate to his emissions being described in *tonnes CO2* equivalents. He put it as follows: *What is it? I have eight tonnes CO2... it is not really obvious what it is....* He continued to say that he did not feel like the reliability of the system was good enough, and after several cases such as the one mentioned above, he gave up on categorising more transactions as he thought it was too hard and there were too many transactions to go through. Several participants also had difficulty re-categorising certain transactions themselves due to not remembering what a transaction concerned, especially if it was a few months back in time. Internet payments through a third-party provider (e.g., Klarna[1]) represented a particularly hard problem, as these transactions usually only have the name of the third-party (e.g., "klarna"), making it hard to discern what the transaction really was for, if it was for a book or a new pair of shoes or something else. The problems mentioned above caused people to feel that the footprint given were still more like an estimate rather than the correct and true calculation of their emissions. For example, P3 noted, when asked if he thought the app provided him a fair picture of his emissions: *It is a bit early still, it becomes a bit too hypothetical I feel like to really give a good answer [to that question]. In a couple of weeks or months.* Apparently, P3 was expecting the numbers to become more reliable over time. P1 was one of the few who thought the numbers and his carbon footprint was correct, or at least as correct as they could be, but also said it is hard to know *how* true and scientific the calculations really are. Despite the problems with the categorisations, P3 still thought that it was best if people would connect their bank account so they could get real facts and not only rough estimates.

The reactions toward the use of external data sources were not all negative. Svalna for instance makes use of registry data to ease the input of data when creating an emission profile. The user can for instance choose to enter their car registry number, which allows Svalna to retrieve information about the brand and fuel consumption of the car. Interestingly, this feature was perceived mainly positively by the participants because it made data input fast and easy, but without causing doubt about correctness. P2 for example reacted as follows to the app explaining that it would look for communal registry information about her housing: *Ah! Cool! It was like, I started filling in [the text fields] without even reading what I was supposed to enter.* And P4 stated *Wow, it knew already!* when the app found information about her housing. P4 also reacted positively to the app automatically filling in information about her car based

[1] www.klarna.com

on the registration number: *It shows exactly how much I drive and everything. Ah. That was good.*

Based on their experiences with the use of transaction data, several participants suggested improvements. First of all, they thought that it should be possible to detail that transactions from certain stores should be split in e.g., half or in thirds depending on their purpose. This could be useful when sharing the cost of a purchase between people, such as the cost of buying a piece of furniture or buying groceries. Several of the participants also expressed a wish to add more information about their lives in order to better reflect their situation and choices. P4 explained: *For example I have a summerhouse. Like, I have a second house. That is something you should be able to add somewhere.* This dissonance between how well the app is able to capture reality and what actually goes on in the lives of the participants is further emphasised by the fact that the emissions calculated for each transaction do not reflect what was bought, only the amount of money spent on a certain category of transaction (e.g., rent, restaurant visits, jewellery). P1 also said that, for him at least, information in the app about how to reduce his emissions needed to be as concrete as possible in order for him to be able to act upon it. A suggestion was therefore to add a feature allowing the user to see exactly what emission sizes the different choices generate, such as choosing alternative modes of transportation or renting instead of buying. Finally, a suggestion was to allow users to detail if they saved money in sustainable securities.

4.3 Groups and social dynamics

Finally, we were interested in the participants' thoughts on joining a group as part of Svalna. Several participants expressed hesitation toward wanting to share and compare themselves to others, being both positive and critical to the concepts of groups in the app. Overall, the participants expressed a sensitivity towards sharing their own carbon footprint with others, with the majority of participants being sceptical to doing so. Some of the participants were more sceptical than others, such as P3: *I don't really have a need to share... everyone should take responsibility for themselves somehow. I don't use social media much... I am quite restrictive with stuff like that.* P2 said explicitly that she did not want to share her carbon footprint, and hinted at some reasons, saying that she maybe was not too proud of her own footprint and did not want to put it on public display. The willingness to share information about their carbon footprint also depended partly upon the kind of information that would be shared. P1 and P4 said that *if* they would share information about their carbon footprint, they would want to share more general, summarised information and not in any way detailed information such as emissions at the transaction level or what they emit daily. Another reason for hesitation to use the group feature was related to how well the participants trusted the numbers and calculations provided by the app. The group feature was thus something that the participants had spent little time with. Despite this, both P1 and P3 said that they would be open for creating a group together with friends or family, though it became clear that it really depended upon who is part of the group and to whom one is compared. P4 said that it would be more interesting to be compared with people similar to herself, and therefore did not see a need to start a group with others. P2 stated that she did not have an interest in groups as she had no competitive spirit.

Even though sharing their carbon footprint with others was a sensitive issue, and forming a group depended upon who would be part of it, most of the participants saw a potential benefit in groups. P1 thought groups could create a solid base for discussions and imagined that groups could be used to "kick-start" a conversation amongst people on these issues. Several participants also noted that they did not think it would work to only have a group in the app, but that something more was needed. Things that were mentioned to give the group feature the extra push were: dedicated members of a group that would contribute to creating discussions, competitions within the group, social activities in real life, a positive employer, as well as ways to interact with each other in the app. P1 and P3 imagined that a common challenge could be motivating and create a sense of community.

4.4 Sustained use and effects of Svalna

In the two to three weeks after the introduction to Svalna, before the second interview, the participants had spent a varying amount of time with the app. Two of the participants had spent around five to ten minutes with it (P3, P4), while P1 estimated that he had played around with the app on several occasions amounting to ca. 30 minutes in total. Both P3 and P4 said they either did not have time or had no interest to look at the app except from having another look just before the interview. P3 mentioned one reason for not being interested in using the app: *...I am probably not so interested in learning more... I know what I need to do in order to reduce my emissions and that is to travel less because that's where I emit the most. I do not feel like I need to follow more closely what more there is [to see].* Most of the participants said that they had taken a closer look at the app and tried to get an understanding of their emissions in more detail (P1, P2, P3). Some of the participants also briefly mentioned how they imagined using the app in the future. P1 said he would try to spend more time with the app, maybe once a month to keep track of things. P1 also raised an important issue about use of the app overall, saying that he thinks there is a risk or danger that people will only use the app once if there is nothing more to keep the "questions" alive. He said that opening the app a week from now would most probably show the same data as today, and that people might not open the app again after that, thinking that there is no benefit using the app frequently. He did not only highlight this risk, but suggested how engagement could be retained, saying that *...I think it needs to "live" and groups are a contribution to make it so, but I think it needs to be more lively. There need to be loads of things happening that give me value and tips along the way, giving me a kick in the butt in order for me to get on with these questions....*

Although several of the participants did not really trust the calculations and carbon footprint provided by the app, P1, P2 and P3 said that they had started to think more about their behaviour and all the smaller choices that have an impact. P1 and P3 also highlighted that the app provided facts that could be acted upon, compared to earlier when they only had their subjective understanding and assumptions about their carbon footprint. On the other hand, P4

said that she did not think using Svalna had led to any changes in how she lived her life or her understanding of her emissions.

Despite the participants' general interest in sustainability, several of them described a tension between doing good for the environment, and wanting to do what they enjoy. Personal freedom was valued highly amongst the participants. While it was important for the participants to be able to do what they want, they also showed a willingness to change or tweak certain behaviours, but not stop completely. This was particularly evident when it came to travelling and flying. P2 put it this way: *Flying less is doable of course, but to completely stop flying I would not be able to do. I could also eat less meat, but not stop completely since I am so interested in making food....* The participants clearly indicated that there were tensions between trying to act more sustainable, and there being obstacles to doing so. P1 described a situation with him and his family trying to buy groceries with as little packaging as possible, but ending up with a lot of packaging anyway as every little thing they bought had some sort of plastic and/or paper packaging. P4 mentioned this as well, calling for a need to make it easier to make sustainable choices.

5 Discussion and conclusion

This paper has investigated the use of and reactions towards a carbon calculator that has two rather unique features: it supports the use of transaction and registry data to calculate people's carbon emissions, and it allows people to form groups. In order to investigate this, we performed two rounds of in-depth interviews with four users. The first interview was held in relation to their introduction to this carbon calculator, while the second interview was held two to three weeks later, in which the participants were allowed to use the carbon calculator as they pleased.

The results from our study reveal several key insights about the use of transaction data to calculating the carbon footprint of people, and highlight both possible opportunities and challenges with introducing groups in the context of a carbon calculator. Concerning the use of transaction data to calculate emissions, all participants expressed a distrust or lack of confidence in the correctness in the carbon footprint presented in the app. The one participant who chose not to connect her bank account did not feel convinced that it was correct, while the three participants who did choose to do so noticed problems with faulty categorisation of their transactions. In many cases the carbon calculator suggested wrong categories for transactions, and it was seen as cumbersome to correct everything, leading to at least one participant giving up on correcting them all by hand. The consequences of mistrusting the carbon footprint provided by the carbon calculator can be many, such as dismissing the results as false, unwillingness to use other features of the calculator, and loss of engagement over time. An important first challenge for any carbon calculator using transaction data is therefore probably to find ways to make people trust the calculations. More information does not automatically lead to more trust if people notice mistakes or doubt the correctness of the estimates. Although it could be argued that our results show that Svalna was not mature enough to be tested with users because it showed some miss-categorisations, we argue that there is another more profound problem. Making a completely infallible system is very challenging, if not impossible, especially when dealing with transaction data that is hard to classify, such as from third-party providers.

However, the use of registry data, which also helps to make estimations more correct, was appreciated a lot by the participants. By filling in the registration number of their car and their address, the system can gather key information so that the user does not have to look up and fill it in manually. If technically possible, we think any carbon calculator should provide this option, because it both saves time for the user, and it is more likely to be more correct than if users make a rough estimate themselves because they do not want to spend time to look it up.

While most of our participants appreciated the thought of using groups, it was clear that the kind of data shared in such a group is extremely important to consider. There is probably a delicate balance between sharing too much data, which makes users feel exposed, and too little data, which may risk making the group section less interesting to users. The participants' interest in groups also depended on who would be part of a group and with whom the participants would be compared with. For instance, the participants favoured more personalised comparisons over more general ones, i.e., being compared with other people leading similar lives rather than to national averages. However, a clear risk with such an approach is that people remain in their comfort zone without realising that the emissions of the group are well above the reduction recommendations to keep the earth's warming below 2 degrees Celsius. Some carbon calculators, like the ISCFC carbon calculator [14] do provide users with information about this target but without creating groups. The message in the ISCFC carbon calculator is e.g., "Note that a 'globally sustainable' footprint level, where atmospheric $CO2$ levels would stabilise at 450ppm, is approximately 1,000 kg (= 2,204 lb) per capita!" It is thus important to consider what kind of comparisons are made in this context, and how these comparisons are relevant to the users. An important aspect of being a part of a group is also that there is enough interaction and activity. While this could happen within the carbon calculator itself, our participants also envisioned the use of the carbon calculator as part of an off-line group. Indeed, organisations such as the Dutch KlimaatGesprekken [16] do use a carbon calculator spreadsheet as a start for their workshop series. Although they also urge people to keep a diary about their travelling, consumption and household use of gas and electricity during the workshop series, this is a hard thing to do for many participants. Making use of a carbon calculator that is able to detect behavioural changes through the use of transaction data, could be a useful solution for such groups.

The participants in our study indicated that their use of Svalna had made them more aware of their impact, and had given them some inspiration to make smaller changes. However, in order for them to keep using Svalna, they thought it would be very important to provide new information on a regular basis in order for them to use it over time. The use of groups could be a part of this, but additional prompts for action from the carbon calculator itself would also be necessary.

As the field of climate psychology has pointed out several times, making people see the urgency of the situation and act upon it in an appropriate manner is extremely difficult. The participants in our study clearly showed this ambivalence, where they wanted to do the right thing, but also were hesitant to give up parts of

their lifestyle and the things they valued. Another problem is that the users of carbon calculators are likely to be people that are at least somewhat interested in sustainability on an individual level. In our study, we indeed had participants who had volunteered for our study, so they were probably more interested than the general public.

We are aware that our sample size of four participants being involved in both interviews is very small. We therefore do not pretend that our results can provide insights into the effectiveness of Svalna. However, as suggested by Nielsen [19], in order to detect usability problems in a technology, a sample size of around 5 participants is usually sufficient. We therefore do think that the concerns and suggestions raised here are still useful for further development of Svalna as well as other carbon calculators. We intend to further study several aspects of the possibilities and difficulties with group functionality in a series of studies during the coming year. Based on the results of the study presented here, we are currently improving Svalna and we are also planning a larger study of the effectiveness of Svalna with a representative group of users in the near future.

Acknowledgments

Many thanks to the participants for their time and commitment and to Uppsala municipality for arranging contact with the participants. This research is part of the programme Mistra Sustainable Consumption, funded by Mistra - The Swedish Foundation for Strategic Environmental Research (Grant number 2016/3).

References

[1] Georg Aichholzer, Doris Allhutter, and Stefan Strauß. 2012. Using Online Carbon Calculators for Participation in Local Climate Initiatives. In *Electronic Participation*, Efthimios Tambouris, Ann Macintosh, and Øystein Sæbø (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 85–96.

[2] David Andersson. 2020. A novel approach to calculate individuals' carbon footprints using financial transaction data - App development and design. *Journal of Cleaner Production* 256 (2020), 120396. https://doi.org/10.1016/j.jclepro.2020.120396

[3] Kathy Baxter, Catherine Courage, and Kelly Caine. 2015. *Understanding Your Users: A Practical Guide to User Research Methods* (2 ed.). Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

[4] Magnus Bergquist, Andreas Nilsson, and André Hansla. 2017. Contests versus Norms: Implications of Contest-Based and Norm-Based Intervention Techniques. *Frontiers in Psychology* 8 (2017), 2046. https://doi.org/10.3389/fpsyg.2017.02046

[5] Milena Büchs, AbuBakr S. Bahaj, Luke Blunden, Leonidas Bourikas, Jane Falkingham, Patrick James, Mamusu Kamanda, and Yue Wu. 2018. Promoting low carbon behaviours through personalised information? Long-term evaluation of a carbon calculator interview. *Energy Policy* 120 (2018), 284 – 293. https://doi.org/10.1016/j.enpol.2018.05.030

[6] Robert B. Cialdini and Noah J. Goldstein. 2004. Social Influence: Compliance and Conformity. *Annual Review of Psychology* 55, 1 (2004), 591–621. https://doi.org/10.1146/annurev.psych.55.090902.142015

[7] Robert B Cialdini, Raymond R Reno, and Carl A Kallgren. 1990. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. *Journal of personality and social psychology* 58, 6 (1990), 1015.

[8] Andreas Flache, Michael Mäs, Thomas Feliciani, Edmund Chattoe-Brown, Guillaume Deffuant, Sylvie Huet, and Jan Lorenz. 2017. Models of Social Influence: Towards the Next Frontiers. *Journal of Artificial Societies and Social Simulation* 20, 4 (31 10 2017). https://doi.org/10.18564/jasss.3521

[9] Jon Froehlich, Tawanna Dillahunt, Predrag Klasnja, Jennifer Mankoff, Sunny Consolvo, Beverly Harrison, and James A Landay. 2009. UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1043–1052.

[10] Jon Froehlich, Leah Findlater, and James Landay. 2010. The Design of Eco-feedback Technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '10)*. ACM, New York, NY, USA, 1999–2008. https://doi.org/10.1145/1753326.1753629

[11] Donald Green and Ian Shapiro. 1994. *Pathologies of rational choice theory: A critique of applications in political science.* Yale University Press.

[12] Tiffany Grace Holmes. 2007. Eco-visualization: Combining Art and Technology to Reduce Energy Consumption. In *Proceedings of the 6th ACM SIGCHI Conference on Creativity &Amp; Cognition* (Washington, DC, USA) *(C&C '07)*. ACM, New York, NY, USA, 153–162. https://doi.org/10.1145/1254960.1254982

[13] Matthew J Hornsey, Emily A Harris, Paul G Bain, and Kelly S Fielding. 2016. Meta-analyses of the determinants and outcomes of belief in climate change. *Nature Climate Change* 6, 6 (2016), 622.

[14] ISCFC. 2020. International Student Carbon Footprint Challenge. https://depts.washington.edu/i2sea/iscfc/fpcalc.php

[15] Daniel Kahneman. 2011. *Thinking, Fast and Slow.* Farrar, Straus and Giroux, New York.

[16] KlimaatGesprekken. [n.d.]. Home. https://www.klimaatgesprekken.nl/

[17] Le Quéré et al. 2018. Global carbon budget 2018. *Earth System Science Data* 10 (2018), 2141–2194. https://doi.org/10.5194/essd-10-2141-2018

[18] Bella Martin and Bruce M. Hanington. 2012. *Universal methods of design : 100 ways to research complex problems, develop innovative ideas, and design effective solutions.* Rockport Publishers, Beverly, MA.

[19] Jakob Nielsen. 1994. Usability Inspection Methods. John Wiley & Sons, Inc., New York, NY, USA, Chapter Heuristic Evaluation, 25–62. http://dl.acm.org/citation.cfm?id=189200.189209

[20] Nordea. 2019. Individual carbon footprints now available to 3 million customers using Nordea's digital banking services. https://www.nordea.com/en/press-and-news/news-and-press-releases/press-releases/2019/12-10-08h00-individual-carbon-footprints-now-available-to-3-million-customers-using-nordeas-digital-banking-services.html

[21] J. Paul Padgett, Anne C. Steinemann, James H. Clarke, and Michael P. Vandenbergh. 2008. A comparison of carbon calculators. *Environmental Impact Assessment Review* 28, 2 (2008), 106 – 115. https://doi.org/10.1016/j.eiar.2007.08.001

[22] Marja Salo, M.K. Mattinen-Yuryev, and Ari Nissinen. 2019. Opportunities and limitations of carbon footprint calculators to steer sustainable household consumption - Analysis of Nordic calculator features. *Journal of Cleaner Production* 207 (2019), 658 – 666. https://doi.org/10.1016/j.jclepro.2018.10.035

[23] Elizabeth Shove, Mika Pantzar, and Matt Watson. 2012. *The dynamics of social practice: Everyday life and how it changes.* Sage.

[24] Gert Spaargaren. 2011. Theories of practices: Agency, technology, and culture: Exploring the relevance of practice theories for the governance of sustainable consumption practices in the new world-order. *Global Environmental Change* 21, 3 (2011), 813–822.

[25] Henk Staats, Paul Harland, and Henk A. M. Wilke. 2004. Effecting Durable Change: A Team Approach to Improve Environmental Behavior in the Household. *Environment and Behavior* 36, 3 (2004), 341–367. https://doi.org/10.1177/0013916503260163 arXiv:https://doi.org/10.1177/0013916503260163

[26] Sarah E. West, Anne Owen, Katarina Axelsson, and Chris D. West. 2016. Evaluating the Use of a Carbon Footprint Calculator: Communicating Impacts of Consumption at Household Level and Exploring Mitigation Options. *Journal of Industrial Ecology* 20, 3 (2016), 396–409. https://doi.org/10.1111/jiec.12372 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1111/jiec.12372