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Title: Opportunities and limitations of carbon footprint calculators to steer sustainable household consumption – analysis of Nordic calculator features

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Abstract

The current patterns of household consumption are environmentally unsustainable, especially in wealthy societies such as the Nordic countries. Globally, housing and energy use at home, travel, food, and the consumption of other goods and services contribute to roughly 60–70% of greenhouse gas emissions. Online footprint calculators have been introduced as a soft policy measure in order to raise public awareness of the carbon footprint of ordinary living. We examined ten calculation tools and interviewed six calculator hosts to study calculator features and hosts' expectations and experiences on engaging people to use calculators and to steer consumption. Our findings show that knowledge intensive calculators are designed to support a rational reflection of lifestyle and activities from an environmental perspective. Tips and pledges are presented in calculators to support taking action. However, engaging people to use calculators, especially more than once, is often considered to be challenging. We further discuss our findings with a framework based on practice theories and point out how features of calculators hold potential for further development, as well as have limitations. The limitations should be taken seriously in considering the role of calculators in policy-mixes to steer household consumption. We also propose that future studies on calculators would benefit from practice approaches in order to further explore patterns of calculator (non)use and how calculator use is (dis)connected from the practices they aim to change, and to avoid over emphasising the role of knowledge in reconfiguring practices.

1. Introduction

The unsustainability and inequality of current household consumption patterns is evident (Hoekstra and Wiedmann, 2014), and the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) are among the wealthy societies with high consumption-based footprints (Hertwich and Peters, 2009). The consumption-based perspective, in addition to the territorial approach, has been recognised to be relevant in the climate change mitigation policies and measures (Creutzig et al., 2018; Girod et al., 2014; IPCC, 2014; Nissinen et al., 2015; Peters and Hertwich, 2008). Roughly, 60–70% of global greenhouse gas (GHG) emissions can be traced to household consumption (Hertwich and Peters, 2009; Ivanova et al., 2016; Seppälä et al., 2011) and household consumption is considered to be an important driver of GHG emissions (Druckman and Jackson, 2016).

The development of databases and calculation methodologies, such as environmentally extended input-output models, has allowed the introduction of consumption-based per capita indicators and their use in policies (Kokoni and Skea, 2014; Wiedmann, 2009). The consumption-based indicators are valuable as they take into account international trade flows and illustrate per capita differences between nations (Hertwich and Peters, 2009) and sub-national populations (e.g. Wiedenhofer et al., 2017). Ivanova et al. (2016) highlight the potential of household footprints in helping to understand the social determinants of environmental impacts, and responding to a lack of information at a household level on required changes in consumption. Consumption-based emission data have been used for informing policy making, individuals and persuading consumers to take responsibility for consumption (Kokoni and Skea, 2014). I.e. consumption-based policies are often related to soft-measures, compared to numerical targets and binding policies related to territorial emissions. In addition to top-down estimations, databases and methods can be applied to bottom-up calculations, e.g. using individual consumption patterns to calculate a personal footprint.

The negative environmental impacts of consumption are often invisible in our everyday lives (Røpke, 2009). To illustrate the impacts, carbon, and other environmental footprint calculators have been introduced by research and non-governmental organisations, and companies. The overall purpose of the calculators is similar, to illustrate invisible impacts and steer sustainable consumption. However, detailed definitions on what to include and exclude from the footprint calculation vary from one calculator to another. Often, calculators focus on consumption patterns and choices: how we arrange our housing (the size and type of home, the type and amount of energy consumed); every day and long-distance travel; the type and amounts of food we buy and consume; the purchase of goods and services, including e.g. electronic devices, clothing, cultural and recreational services.

The existing literature on calculators for citizens is limited. Consulted literature provide two perspectives: One approach focusing on calculation methodologies (Birnik, 2013; Čuček et al., 2012), and inconsistencies of calculators (Padgett et al., 2008). This stream of literature has concluded that transparency, consistency and data quality should be greatly improved, because calculators influence behaviour and policies. Following this line of thinking, papers describing the methodologies of calculations, such as Matuštík and Kočí, 2019, and Nahar and Verma, 2018, are greatly welcomed. The other approach focuses on calculator use in empirical studies that aim to change household and individual consumption patterns. So far, empirical studies on carbon or other environmental footprint calculations, and on calculators used in sustainability interventions and campaigns, show varying results in changing self-reported consumption patterns or footprints (Hunter et al., 2006; Sutcliffe et al., 2008; Bartiaux and Salmón, 2012; Laakso and Lettenmeier, 2016; West et al., 2016; Salo et al., 2016). Major limitations of the empirical studies on calculators and their impact on the change of consumption patterns include: a limited number and diversity of participants (possible biased environmental awareness), the quality of self-reported data, and a lack of a long term follow-up. Both of the above mentioned streams of literature build on the assumption that the information provided by the calculators leads to a change in consumption patterns or policy.

There is a knowledge gap on effective ways to promote and support sustainable household consumption with communication measures and assessment tools, including calculators, and on the need to address the social and cultural embeddedness of routines and practices (Caeiro et al., 2012; Gram-Hanssen and Christensen, 2012). Some scholars take a more critical stance on the role of calculators in steering household consumption. Spaargaren (2011) claims that the calculators have increased the level of environmental awareness, but this does not translate to environmentally friendly behaviour. Indicators carry value positions (Lyytimäki et al., 2013), and individual footprinting is referred to as an example of the individualistic behaviour change approach (Spaargaren, 2011), which has been criticised for placing too much emphasis and responsibility on individuals (Shove et al., 2012). In other words, the underlying assumption of calculators that more or better information linearly leads to changes in consumption has been questioned (Shove, 2003, 2010). Practice theories are the basis for the critique of Spaargaren and Shove (ibid.) on calculators. While practice approaches have become popular in studying sustainable consumption (see Section 2), they are not yet fully harnessed to study the opportunities and limitations of the footprint calculators.

Footprint calculators seem to create an arena for opposing approaches on steering household consumption. On one hand, critique has been raised on the power and even the justification of focusing on individual footprints and responsibility. On the other hand, up-to-date methods enable one to estimate top-down and bottom-up carbon footprints per capita and the footprints can be seen as potential (soft) policy measures for sustainable consumption. We position our research as part of the discussion on how to steer household consumption patterns towards the goal of a sustainable per capita carbon footprint.

In this paper, we study the features of existing online footprint calculators and the expectations and experiences of calculator hosts on the use of calculators in sustainable consumption initiatives. By features, we refer to aspects of the calculator that (are intended to) serve a certain purpose. The concept of a feature is widely used in software development (e.g. Apel and Kästner, 2009). In this paper, we also consider the type of data input, the format of results or guidance on taking action as features of the calculators.

We reframe our findings on calculators and their use with practice theory approaches in order to discuss the potential of calculators in steering consumption. The research questions are:

1. What do calculator features tell about hosts' expectations on patterns of calculator use?
2. What kind of challenges have the calculator hosts experienced in using the calculators in sustainability initiatives?
3. From a practice perspective, what are the opportunities and limitations of calculators to steer consumption?

2. Sustainable consumption and theories of practice

The question of how to make consumption more sustainable has been addressed by various research traditions. The practice theory perspectives on sustainable consumption and production systems are often presented in contrast to established traditions. For instance, Geels et al.(2015) refer to socio-technical systems and practice approaches as the middle way in moving beyond established reformist (demand and supply of eco-efficient products, focus on incremental changes and technological solutions) and revolutionary (taking a critical stance on modern capitalism and consumerism with an emphasis on sufficiency and frugality) positions on sustainable consumption and production. Also, Keller et al., (2016) differentiate social practice theory from other research traditions on sustainable consumption, such as: individual behaviour change; behavioural economics; and technological change.

According to the theories of practice, our everyday lives are not (only) manifestations of carefully considered, individual, rational choices, but rather bundles of interlinked practices: a mix of routinised and conscious decisions on how to arrange our everyday life, within the given social and physical environment (Reckwitz, 2002; Warde, 2005; Shove et al., 2012; Spaargaren et al., 2016). Household practices are dominated by life-world rationalities, in contrast to different rationalities of production and processing (Spaargaren et al., 2012). Reckwitz (2002) describes how individuals are "…carriers of a practice, they are neither autonomous nor the judgemental dopes who conform to norms: They understand the world and themselves, and use know-how and motivational knowledge, according to the particular practice." The perception of agency of people is relevant from the calculator perspective, as it leaves space for, but without over emphasising, the role of reflective activity.

Reckwitz (2002:249) sees a practice to consist of interconnected elements of: "forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge." Shove et al., (2012) present three elements of practice: Material, referring to tangible objects; meanings, including the socially shared understandings; and, competences, such as skills and capabilities of doing things. Spaargaren et al., (2016) claim that the interpretation of Shove et al. (ibid.) focuses on the material arrangements and argue for the importance of non-material elements in organising practices. Here, they refer to the work of Schatzki (1996, 2002) on understandings, rules and teleoaffective structures, i.e. ends, tasks, emotions, that are interpreted as integrative properties of practices.

While scholars have a different emphasis on the role of elements and agency in practices, they agree that the unit of analysis is a practice, instead of an individual person. Often, practice approaches place the everyday (ordinary) consumption at the focus of the analysis (see Gronow and Warde 2001 for ordinary consumption). Examples include cleanliness (Shove, 2003), food consumption (Laakso, 2017a; Warde, 2016), mobility (Aro, 2016; Laakso, 2017b), energy consumption (Gram-Hanssen, 2014, 2009), smart energy systems (Carroll et al., 2014; Hargreaves et al., 2013; Naus et al., 2014), and energy efficient lighting (Genus and Jensen, 2017). The listing above illustrates how practice scholars have already studied the areas of consumption that also calculators address. While case studies often focus on certain practices, it is important to recognise how practices are interlinked (Shove et al., 2012). For instance, everyday travel is linked to several other practices, as shown later in this section (Figure 1.).

Practice approaches have also been used to assess sustainability interventions (Evans et al., 2012; Spurling et al., 2013; Sahakian and Wilhite, 2014), consumer oriented environmental politics pilots (Spaargaren, 2003), and the role of experimentation on household energy transitions (Jalas et al., 2017). Also (Schanes et al., 2016) refer to practice concepts in assessing behavioural strategies and consumer choices. We take a closer look at work by Spurling et al. (2013), who build on Schatzki (1996), to illustrate how practices consist of observable performance and underlying entities (Fig. 1.). Driving as a performance refers to the act of driving. The underlying entities, on the other hand, consist of three elements: materials, meanings and competences (Shove et al., 2012), as illustrated in Fig. 1. Car driving is linked to other daily practices which driving makes possible or more convenient and allows practitioners to pursue meaningful objectives. The interdependence of practices is illustrated by the bundle of daily activities involving driving, including e.g. taking children to day care, going to work, buying groceries and making it back home in time to have a family meal together. It is relevant to note that there may also be several (conflicting) rationalities and intentions affecting practices that may or may not result in environmentally beneficial practices (see Smale et al., 2017 on negotiating priorities concerning the timing of energy use at home). It is also important to note that new technologies don't merely replace old ones while practices remain the same, but rather practices and the related entities co-evolve with technologies (Mylan, 2015). In the case of cars, they replaced horses, but also allowed a total change to the structure of cities, as well as the space and time dimensions of our lives.

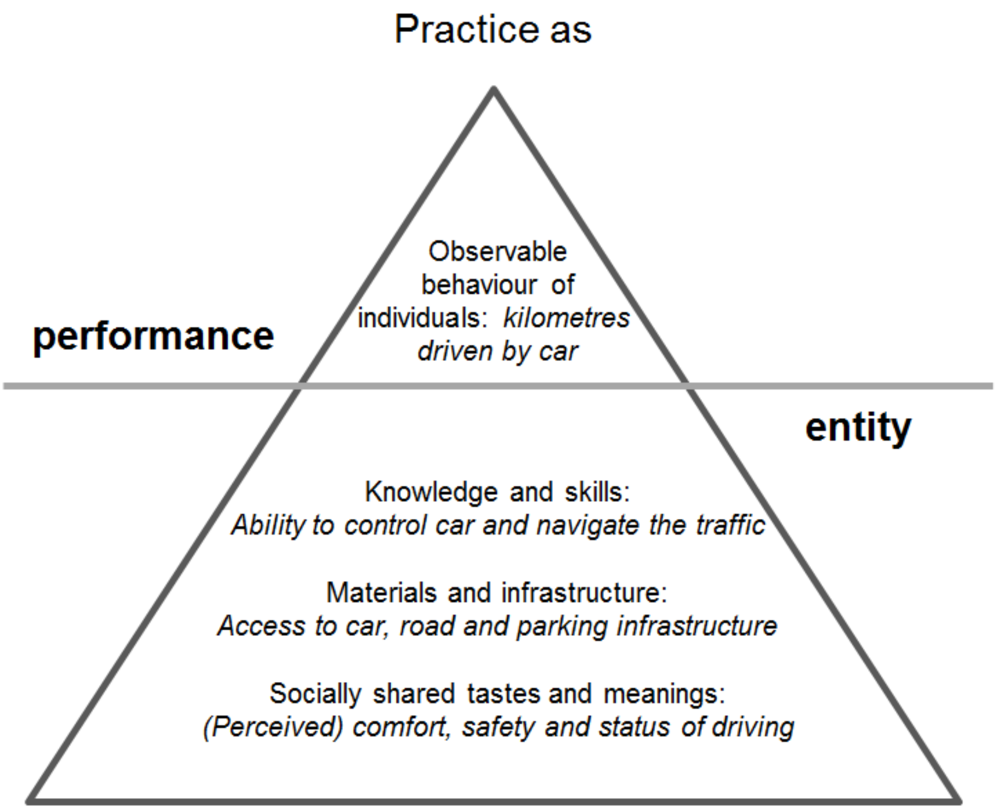

Fig. 1. Car driving as an example of practice as a performance and entity. Modified from (Spurling et al., 2013).

The value of practice approaches for our study on calculators lies mainly in two aspects: First, on how the predominant role of rational decision making is challenged, and second on how the elements of practices illustrate the connections, dependencies and complexities of our everyday activities. The differentiation of practice as a performance and as an entity is recognised as a potential avenue for studying ways to steer sustainable consumption (Laakso, 2017c). In the case of calculators, this distinction may help to broaden the perspective "ill-served by a focus on instances of behaviour or purchasing decisions."(Genus and Jensen, 2017) or design for sustainability solutions focusing too narrowly on incremental improvements (Kuijer and Bakker, 2015).

We study calculator features in order to identify the expected patterns of calculator use. As calculator features are designed and implemented to serve certain purposes, they may reveal underlying assumptions of rationalities regarding patterns of consumption and intended impacts. In Section 5, we use the elements of practice to reframe our empirical findings on calculator features and hosts' experiences in order to identify opportunities, challenges and limitations of calculators in steering consumption.

3. Materials and methods

The data collection included: systematic examinations of calculators and their features, public documentation of calculators (if any), expert interviews of the calculator hosts, and literature review (peer reviewed articles related to calculators, if any). Types of data complement each other in telling the story of the calculators. By studying the calculators "as they are", we attempted to learn how hosts expect users to engage with calculators and what kinds of actions they are expected to take as a result of the calculator use.

The examined ten online calculators provide similar functionality for the non-professional user: the user gives information about one's own consumption, and the calculator provides tailored feedback on the CO_2 or GHG emissions on one or several areas of consumption: housing, travel, food, consumption of other goods and services. By tailored feedback, we mean that the user is able to specify aspects of consumption to gain personalised results, instead of country averages, for instance. The practical purpose and use of the calculator were in focus, rather than following certain technical or methodological definitions. We focus on calculators from the Nordic countries, as they are all affluent countries with high average per capita footprints on the global scale.

To clarify the use of certain key concepts in this paper, we note that what is seen as consumption in the footprinting methodologies e.g. kilometres travelled and units of energy consumed, is part of everyday practices, such as commuting to work, cooking meals and heating or cooling our homes. Although consumption is not a practice, it is an inseparable part of many practices. In this paper, we use, in parallel, the concepts of consumption pattern and every day practices to refer to components contributing to footprints.

Calculators were searched from the Internet by using keywords in the local languages of the Nordic countries. In addition, local experts in the field of sustainable consumption and calculators were contacted to identify potentially missed calculators during the search. We are aware that our data does not cover all the carbon footprint calculators available for Nordic citizens in their own languages. However, we argue that our data is extensive enough to provide an overview of calculator features and hosts' experience in their use. In addition to Nordic calculators, we consulted two calculators outside the region: Climate Neutral Now, due to its ambitious global outreach, as this may affect the features and questions, and WWF UK calculator, as it was considered to be a well-established and designed tool to be included as a reference from this perspective. The data were collected in a study by Salo and Mattinen (2017). The list of the examined calculators and background materials consulted, in addition to the calculator, is collated in Table 1. The links to calculator websites are listed after the References.

Table 1 List of examined calculators and materials used in addition to the online tools.

Name of the calculator	Host organisation	Country	Documentation	Interview	Peer reviewed article
Baltic Sea Card	Ålands Bank	Åland / Finland / Sweden			
Car comparison calculator	Orkusetur (Energy Agency Iceland)	Iceland		yes	
Climate Neutral Now	UNFCCC United Nations Framework Convention on Climate Change	Global	Provided on request	yes	
CO_2-beregneren	Energi Tjensten (Energy Agency Denmark)	Denmark			
Ducky	Ducky as	Norway	Available on the website	yes	
Ilmastodieetti	Finnish Environment Institute SYKE	Finland	Available on the website	yes *	Salo et al., 2016
Klimatkontot	IVL Swedish Environmental Research Institute	Sweden	Available on the website	yes	
Kolvidur calculator	Kolvidur Fund	Iceland			
Min klimatpåverkan (REAP Petite in UK)	SEI Stockholm Environment Institute	Sweden (and UK)	Available on the website	yes	West et al., 2016
WWF UK environmental carbon footprint	WWF (World Wildlife Fund) UK	UK	Available on the website		

*The first author of this paper is a representative of the Ilmastodieetti calculator and has been involved in the development since the calculator launch in 2010.

We developed a template for the desktop examination and to be used as an outline for the interview. The template was inspired by the studies of Caeiro et al. (2012) and Birnik (2013), and included:

- Descriptive information of the calculator: name, link, languages available, year of launch and updates, organisation responsible for hosting the calculator, target audience, description of documentation.
- Methods, data and scope: calculation methodology, data sources, covered footprint and consumption categories, type of consumption input (how can users specify their consumption patterns and choices).
- Calculator features to engage users: type of feedback and results presented to users, proposals for action, type of information, the possibility to see ones' progress over time, social features (e.g. group features, share buttons for social media).
- Marketing and interventions (campaigns and other initiatives): description of campaigns to increase the number of visits, interventions (e.g. research projects, campaigns) in which the calculator has been used, user feedback collection and use.
- Calculator use and impact: the number of users in the calculator (e.g. in a certain year, since launch) and description changes over time, target for the number of users, data on the calculator impact on consumption patterns.

All of the calculator hosts were invited to an interview to be conducted by phone or Skype. Altogether six calculator representatives were reached for a semi-structured interview. The purpose of the interview was to discuss issues on calculator use in campaigns and other activities, the number of users and the measured impact as this type of information was not available on the websites. While we did not reach all hosts for an interview, the calculator websites and publicly available information provided relevant information for our study. For instance, the features and, therefore, the specific concept, data sources, purpose and use context of the calculator could be identified. Data were collected in June-November 2016.

4. Results

Based on the desktop study and interviews, we listed features of the calculators and grouped them in four overarching categories: *Recruiting users, Usability*, *Knowledge*, and *Support*. The categories reflect the flow of the expected pattern of use and the purpose of the calculator. *Recruiting users* includes activities to raise awareness of the calculator and motivate calculator use (see Appendix). *Usability* refers to features that enhance the ability of people with varying levels of previous knowledge on the topic to get started and proceed with the calculation in a meaningful way. Usability features also support users in completing the calculation without detailed numerical data on their consumption patterns. *Knowledge*, on the other hand, refers to features that aim to increase knowledge of the footprint and its relevance to the climate issue. Knowledge features also inform about the footprint composition and the order of magnitude of the different consumption categories. Personal footprint results and seeing the typical consumption patterns increase knowledge. The *Support* category includes calculator features and also real-life activities that aim to encourage taking action. Support can be practical advice, the possibility to follow-up a personal track-record, social features showing the contribution of others. Support also includes activities, e.g. meeting with peers or sustainability experts.

4.1 Recruiting users - raising awareness of the calculator

The potential of calculators to raise awareness and reconfigure practices can only be realised if they are used. Calculator hosts shared their experiences on recruiting users and the use of calculators in research projects, community level activities, municipalities, at schools, by NGOs, through organisations' internal networks, and business partners. Based on the interviews, the role of intermediaries is important in reaching potential users. Often, calculators are hosted by research organisations and there may be lack of direct contacts to users. Campaigns and visibility in media, often as a result of collaboration with an NGO or media partner, were mentioned as potential and proven means to increase calculator use, at least, temporarily. Also, in order to reach environmentally unaware people, face-to-face recruiting in public spaces was mentioned by two calculator hosts.

Some calculators were designed for a certain purpose or use context, e.g. schools (CO_2-beregneren), calculating costs and emissions of private driving (Car comparison calculator), or attached to online banking services and purchase transactions (Baltic Sea Card). Also, some potential, but at this point very general, future possibilities were mentioned: workplaces, gamification and tools for comparing choices when buying things.

Freely available online footprint calculators have, in principle, a potential to reach a large number of people. We collected data on the number of users the calculators have reached. The figures are fully reported in (Salo and Mattinen, 2017). To summarise, altogether the number of users was moderate and many interviewees noted that they had expected to have more users, although often numerical targets were not defined. The highest number was approximately 20,000 per year on average and the range was from 1,000 to 122,000 users during the entire life time of the calculator.

4.2 Usability – supporting users to complete their calculation

The next step after reaching the users and having them visit the website is to support them in completing the calculation. Several comprehensive calculators have features that help users to fill in and estimate consumption data i.e. kilowatt hours of energy and litres of fuel, if users lack the exact numbers. Some calculators may also ask for preferences or more generally, or provide qualitative descriptions to choose from. This applies in particular to food consumption, as many calculators provide descriptions of diets to choose from, but also to shopping, for instance.

An important part of usability development is taking user experience and feedback into account. According to interviews, feedback collection is mostly reactive, e.g. users send emails about problems or suggestions to developers. Feedback can be taken into account in updates and new releases of the calculators. Ducky is an exception in these respects and takes users more actively on board already during the development.

4.3 Knowledge – making people aware of their impact

Comprehensive calculators illustrate what matters: typically housing, travel and food make up roughly three quarters of the footprint. Calculator hosts stated that calculators are good tools to raise awareness and provide information. For instance, Ducky introduces everyday actions, such as meal choices or walking and cycling, and a car comparison calculator concerning the emissions produced through using a certain type of car.

While calculators include a great deal of information, it was also noted by interviewees that too much information does not help to deliver the main message. The strength of calculators is to illustrate and tailor person and household-specific estimates of the GHG emissions from consumption. The numbers presented have to be meaningful and understandable. Therefore, many calculators provide comparisons per capita on country or neighbourhood averages, or the sustainable global level. However, showing the global sustainable per capita footprint brings about a communicative challenge: One interviewee highlighted that even if the user actively takes suggested actions, the total contribution is small due to the high emissions of basic necessities of housing, food and personal transport in affluent societies. Therefore, it is difficult to achieve the sustainable footprint which can lead to frustration.

In addition to individual footprints, e.g. the WWF UK calculator shows a per capita government footprint on top of the personal footprint. A person cannot affect the size of a government footprint through purchase decisions, but it is important to note that footprints based on e.g. consumption expenditure do not show the total impact, especially in countries with a strong public sector with extensive public services, such as education and health care.

4.4 Support – suggestions on how to make ones' footprint smaller

Nine out of the ten examined calculators list tips or pledges on how to make one's footprint smaller. While the Climate Neutral Now and Kolvidur calculators only provide a possibility to pay for carbon offsets, most calculators provide tips to make footprints smaller. For instance, pledges in the REAP Petite UK calculator include the following: Replace all my lights and appliances with energy efficient ones, when needed; Walk or cycle to my local shops rather than drive to the supermarket; Use eBay and freecycle to do more of my shopping. In addition to presenting suggestions, the REAP Petite and Ducky also allow one to see the number and types of actions taken.

While many calculators have features that allow users to return to their results to track activities and progress over time, the challenge of engaging people to use a calculator more than once was highlighted by many interviewees. The low number of repeated users was based on user databases of Min klimatpåverkan and Ilmastodieetti. In addition, the experiences from Klimatkontot and Ducky suggest that engaging users over a long time is a challenge.

Some of the studied calculators had been used in sustainability initiatives, including e.g. face-to-face discussions or group meetings. In addition to contact with an expert advisor or a group of peers, it was also possible to share and see experiences and contributions online in some calculators. Online social features were especially important in Ducky.

Calculator hosts recognised the complexity of everyday life and changing consumption patterns. Interviewees emphasised that the calculators need to be part of a larger campaign and listed policies, such as carbon labelling, that would be needed in parallel to change consumption.

5. Reframing and discussing the findings with practice approach

We argue that exploring the linkages of calculators and elements of practice is fruitful for discussing the challenges of calculators (critique on the individualistic approach as presented in Section 1) and future avenues for calculator take-up and role in steering consumption. This way, we agree with Spurling et al., (2013), who argue that in sustainability policies it is more effective to address the underlying components than the performance aspects of practices. In Table 2, we reframe our findings with the help of elements of practices, as introduced in Fig. 1, and collate the calculator opportunities and limitations.

Table 2 Opportunities and limitations of calculators categorised by the elements of practices.

Elements of practices	Opportunities of calculators	Limitations and challenges of calculators
Knowledge and skills	Possibility to provide knowledge and illustrate hidden impacts of (ordinary) consumption, as well as government footprints. Potential to feed into everyday practices, but also contribute to understanding that policies on a societal level are required to tackle environmental problems. Can suggest how to learn new skills (e.g. vegetarian cooking) that help reconfiguring practices. Sustainability experts can further help to find support. Can add new information to existing online services that people already use and expose people to new knowledge. E.g. Baltic Sea Card combines purchase and emission data, and car comparison calculator shows costs and emissions. Could be used to illustrate impacts as part of a more strategic process aiming at lower impact living. I.e. not only convincing individuals to change their practices, but also design policies, services or products to tackle the issue. Actual and real-time data could alarm about peaks in GHG emissions and clarify the link between emission peaks and certain practices.	Limited ability to directly improve the skills required to reconfigure practices, such as renovation, vegetarian cooking, bicycling. Users may not be aware of their consumption in units such as: km, kWh, EUR. This has implications on the quality of data input, user experience, and the framing of the whole problem of footprints. Usage may be disconnected from the existing practices that calculators aim to change. I.e. the calculator is a separate application that is not present in activities such as cooking, driving or household maintenance tasks. Therefore, the direct feedback is missing. Risk of focusing on incremental changes and suggestions as messages, such as tips and pledges, have to be simple.
Materials and infrastructure	Suggest how to rearrange material elements, to make footprints smaller. E.g. related to heating or cooling solutions, renewable energy sources for home and car, renovations to improve the energy efficiency of home low-energy devices. Calculators would become important material elements in managing personal carbon footprints if	Limited ability to rearrange major material elements to support e.g. low-carbon travel practices if public transport and infrastructure for walking and cycling is missing. Limited support for dealing with the process and possible inconveniences of adopting new technologies e.g. process of purchasing and installing renewable

	personal carbon budgets would be imposed.	energy systems. Suggestion to off-set emissions does not support the reconfiguration of underlying unsustainable practices.
Socially shared tastes and meanings	Social features to share activities, results, tips, and personal progress with peers. Potential platform to show that others are also taking action. Off-line activities, such as group meetings or school education, create opportunities for learning from peers and professionals, organising challenges and competing with each other.	The idea of calculating a footprint may be disconnected from activities and aspirations related to existing practices. If a community using the calculator is closed or very small, the conventions and ideas considered to be normal may not be prevalent in the everyday life context of a wider community and society. E.g. it may not be acceptable or recommended to send kids to school on foot or by bicycle due to concerns for their safety.

Clearly, calculators and their use are soft policy measures (Kokoni and Skea, 2014). Currently, it is a voluntary exercise to devote time and effort to calculate a footprint. It is likely that people with an environmental mind-set (or what Schatzki (1996, 2002) refers to as teleoaffective structures) are potential users of the calculators (Gram-Hanssen and Christensen, 2012). If a person does not find the environmental issues problematic or a priority in his/her life, the calculator may not be relevant. The challenges to face-to-face recruiting of users reported in the interviews may be related to this (see also Salo et al., 2016; West et al., 2016).

The listed opportunities (Table 2) are mainly related to different ways to expose people to knowledge, and, in particular, comprehensive calculators can contribute to what Sahakian and Wilhite (2014:26) call for: addressing the environmental priority areas. Information can be useful when people consciously reflect on what they do. However, Warde (2016) argues that most of the time people are not very reflective about everyday life practices, unless there is a disruption e.g. moving to a new home or a birth of a child. The power of knowledge to change our practices is also hindered if our environment lacks affordances (see e.g. Kaaronen, 2017; Warde, 2016) to invite us to engage in more sustainable forms of conducting everyday practices. An example of affordances is convenient access to waste sorting and recycling facilities. At the moment in affluent societies, material, as well as social affordances and cues to engage in more consumption, are more prevalent than cues for sufficient and low-impact living. A mix of ambitious policies is required to reconfigure material elements and much of this is beyond the direct impact of calculators, which sets a limitation on how much calculators can contribute to change in consumption. However, one avenue for further development and research is to study how calculators or more advanced technical solutions alike could increase the amount of cues for engaging in more sustainable forms of practices. The purpose would be somewhat similar to tips and pledges at the moment, but the design, timing, place and form would be more directly connected to the practice.

The difficulty to provide input data with units of energy, kilometres travelled etc. highlights how the units of e.g. energy are just “side-effects” of completing meaningful activities, such as travelling to meet friends and relatives, maintaining a comfortable temperature at home, and cooking. Shove (2017) argues that the current units of energy are more distant to the original context as the previously used units of man and horse power were during the past. Shove (2003:4) also emphasises that “Environmentally inspired analyses, usually framed in terms of restraint, excess and individual choice, tend to focus on the consumption of energy, water and other natural resources, but not on the services and experiences they make possible. Therefore, the question is not only a technical challenge to improve and ease data input. Most importantly, it illustrates how e.g. (fossil) energy use is built-in and shapes normal everyday life. Practices have co-evolved with technologies such as private cars. That is why tips suggesting relevant reconfigurations from an emission perspective can be problematic from the practice point of view. E.g. suggestions to drive less may ignore the purpose, linkages to other practices, and sequences of practices that driving enables. Also, alternatives such as bicycling may be challenged as the quality of routes and infrastructure may not be of equal quality for both of the transport modes and cars have allowed community structures with vast distances to be developed.

Calculators have a challenging task to combine two objectives: First, to communicate that the current footprint is far from what is considered to be sustainable (as is often the case in affluent countries) and second, to suggest how to pursue a more sustainable footprint. The tone of voice is positive and suggestions to take action include many fairly simple actions to start with. Easy-to-take actions can be problematic due to a risk of focusing on incremental changes (Hargreaves et al., 2013; Kuijer and Bakker, 2015; Mont et al., 2013) and efficiency, which does not question the existing standard of living (Shove, 2017). Calculators implicitly take a stance on how to tackle the issue when they provide tips: Focusing on means of efficiency with as little as possible changes in the existing practice e.g. low-emission car; reconfiguring practice without questioning the purpose e.g. propose taking public transport, instead of a car; or ask to reconsider the number of kilometres or the purpose of the trip. An extreme example is off-setting emissions, rather than questioning and reconfiguring the unsustainable practice.

Personal communication among peers and with sustainability professionals about calculator use can lead to more meaningful interpretations of calculators use. Communication allows discussion on the underlying reasons (elements of practice) of the observed performance. In other words, outputs of the calculators are an initiator for discussions, provide an input for a process, and are not an end as such. The interactions can feed into real-life practices, if they lead to material re-configurations for new lower-impact (transport) services (Laakso and Lettenmeier, 2016; Laakso, 2017b). Calculators as illustrators of impacts could also be used in more strategic processes in addition to personal and neighbourhood activities.

Even if technical aspects, such as more consistent calculation methodologies or automated data collection, would be improved, many of the above listed challenges of calculators remain to be addressed and limitations to be accepted. We argue that calculator development and research would benefit from using the practice methods (Nicolini, 2012) to collect primary data on the use of existing calculators. This could be done e.g. by observing or interviewing people while they use the calculator. Learning from doings and sayings related to how people use the calculator and interpret the use in relation to their life-world rationalities could improve our understanding of the dynamics of the everyday practices and the potential of calculators and the type of features to, or not to, steer consumption. Also, observations could reveal the obstacles of the surrounding material and social environments to reconfigure practices, which is relevant for policy design. In many of the previous empirical studies using calculators, the focus has been on whether the calculator has helped to reduce the size of the footprint. We propose that observing more closely the question as to why calculator was (not) used or everyday practices (not) rearranged accordingly, could provide insights on the underlying elements that should be addressed by policy-mixes and not only individual choices.

6. Conclusion

We examined ten calculation tools and interviewed six calculator hosts to study calculator features and hosts' expectations and experiences on engaging people to use calculators and to steer consumption. We reframed our findings on calculators and their use with practice theory approaches. To answer our first research question on the expected patterns of calculator use, we highlight four points: 1) pledges, tips and features to follow-up personal activity and impact indicate that calculator hosts aim to provide support to change consumption patterns. 2) many calculators have features for repeated use and aim to provide support in the long term. Such features include e.g. the personal history of taken actions and footprint results, pledges, and social features. 3) we show that calculators have a strong emphasis on knowledge and raising awareness. 4) drawing on the findings on features, we interpret that calculator hosts expect users to adopt knowledge, use it to rationally reflect on their consumption and take action to decrease their footprint.

Our second research question focused on the experiences and especially challenges in using calculators in sustainability initiatives. In this respect, the recruitment of users to try the calculator was found to be challenging, but campaigns and visibility in the media have contributed to temporary peaks in the number of users. Regarding long-term engagement, despite the calculator features inviting users to return to the calculator, so far it has been challenging to engage people to use the calculator more than once. Also, hosts involved in activities in sustainability initiatives highlighted that it may be challenging to reconfigure practices, especially in order to reach a sustainable level of footprint.

To answer the third research question, we reframed our findings with a practice approach in order to explicate the opportunities and challenges of calculators in steering consumption from both household and broader policy perspectives. We found practice approaches to be useful in discussing potential reasons for challenges of calculator use. We proposed that future studies on calculators would benefit from using the practice perspective, as it can help to unfold the real-world dynamics of calculator use and the practise they aim to reconfigure. Practice approaches can help to avoid over emphasising the role of knowledge and information in reconfiguring practices and consumption patterns.

The results provide, to our understanding, novel, even if preliminary, findings on calculator features and expected patterns of calculator use, user engagement, and challenges to calculator use in sustainability initiatives. While our focus is mainly on the Nordic countries, we believe that our findings are relevant for members of academia and practitioners also from other affluent countries with fairly similar cultural backgrounds. Another novelty of our paper is to use a practice based framework to discuss the results in order to identify the opportunities and limitations of calculators and their use as a soft policy measure. Our focus was on the host perspective and their experiences on calculator use. The findings from our study highlight potential pitfalls, as well as opportunities that should be further studied from the user perspective. We propose that in order to better understand the potential of calculators as a policy measure, future studies should take a closer look at how calculators are or could be embedded into the everyday practices of people.

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References

Apel, S., Kästner, C., 2009. An Overview of Feature-Oriented Software Development. J. Object Technol. 8, 49. https://doi.org/10.5381/jot.2009.8.5.c5

Aro, R., 2016. Normality against Sustainability - Mobility practices of well-to-do households: Normality against Sustainability. Environ. Policy Gov. 26, 116–128. https://doi.org/10.1002/eet.1705

Bartiaux, F., Salmón, L.R., 2012. Are there domino effects between consumers’ ordinary and ‘green’ practices? An analysis of quantitative data from a sensitisation campaign on personal carbon footprint. Int. Rev. Sociol. 22, 471–491. https://doi.org/10.1080/03906701.2012.730825

Birnik, A., 2013. An evidence-based assessment of online carbon calculators. Int. J. Greenh. Gas Control 17, 280–293. https://doi.org/10.1016/j.ijggc.2013.05.013

Caeiro, S., Ramos, T.B., Huisingh, D., 2012. Procedures and criteria to develop and evaluate household sustainable consumption indicators. J. Clean. Prod. 27, 72–91. https://doi.org/10.1016/j.jclepro.2011.12.026

Carroll, J., Lyons, S., Denny, E., 2014. Reducing household electricity demand through smart metering: The role of improved information about energy saving. Energy Econ. 45, 234–243. https://doi.org/10.1016/j.eneco.2014.07.007

Creutzig, F., Roy, J., Lamb, W.F., Azevedo, I.M.L., Bruine de Bruin, W., Dalkmann, H., Edelenbosch, O.Y., Geels, F.W., Grubler, A., Hepburn, C., Hertwich, E.G., Khosla, R., Mattauch, L., Minx, J.C., Ramakrishnan, A., Rao, N.D., Steinberger, J.K., Tavoni, M., Ürge-Vorsatz, D., Weber, E.U., 2018. Towards demand-side solutions for mitigating climate change. Nat. Clim. Change 8, 260–263. https://doi.org/10.1038/s41558-018-0121-1

Čuček, L., Klemeš, J.J., Kravanja, Z., 2012. A Review of Footprint analysis tools for monitoring impacts on sustainability. J. Clean. Prod. 34, 9–20. https://doi.org/10.1016/j.jclepro.2012.02.036

Druckman, A., Jackson, T., 2016. Understanding Households as Drivers of Carbon Emissions, in: Taking Stock of Industrial Ecology. Springer International Publishing.

Evans, D., McMeekin, A., Southerton, D., 2012. Sustainable Consumption, Behaviour Change Policies and Theories of Practice. Collegium 12.

Geels, F.W., McMeekin, A., Mylan, J., Southerton, D., 2015. A critical appraisal of Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions. Glob. Environ. Change 34, 1–12. https://doi.org/10.1016/j.gloenvcha.2015.04.013

Genus, A., Jensen, C., 2017. Beyond ‘behaviour’: The institutionalisation of practice and the case of energy-efficient lighting in Denmark. J. Consum. Cult. https://doi.org/10.1177/1469540517717781.

Girod, B., van Vuuren, D.P., Hertwich, E.G., 2014. Climate policy through changing consumption choices: Options and obstacles for reducing greenhouse gas emissions. Glob. Environ. Change 25, 5–15. https://doi.org/10.1016/j.gloenvcha.2014.01.004

Gram-Hanssen, K., 2014. New needs for better understanding of household's energy consumption – behaviour, lifestyle or practices? Archit. Eng. Des. Manag. 10, 91–107. https://doi.org/10.1080/17452007.2013.837251

Gram-Hanssen, K., 2009. Standby Consumption in Households Analyzed With a Practice Theory Approach. J. Ind. Ecol. 14, 150–165. https://doi.org/10.1111/j.1530-9290.2009.00194.x

Gram-Hanssen, K., Christensen, T.H., 2012. Carbon calculators as a tool for a low-carbon everyday life? Sustain. Sci. Pract. Policy 8.

Gronow, J., Warde, A. (Eds.), 2001. Ordinary Consumption, 257th ed, Complexity and Emergence in Or. Routledge, London ; New York.

Hargreaves, T., Nye, M., Burgess, J., 2013. Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy Policy 52, 126–134. https://doi.org/10.1016/j.enpol.2012.03.027

Hertwich, E.G., Peters, G.P., 2009. Carbon footprint of nations: A global, trade-linked analysis. Environ. Sci. Technol. 43, 6414–6420.

Hoekstra, A.Y., Wiedmann, T.O., 2014. Humanity's unsustainable environmental footprint. Science 344, 1114–1117.

Hunter, C., Carmichael, K., Pangbourne, K., 2006. Household ecological footprinting using a new diary-based data-gathering approach. Local Environ. 11, 307–327. https://doi.org/10.1080/13549830600558804

IPCC (Ed.), 2014. Climate change 2014: mitigation of climate change: Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY.

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., Hertwich, E.G., 2016. Environmental Impact Assessment of Household Consumption: Environmental Impact Assessment of Household Consumption. J. Ind. Ecol. 20, 526–536. https://doi.org/10.1111/jiec.12371

Jalas, M., Hyysalo, S., Heiskanen, E., Lovio, R., Nissinen, A., Mattinen, M., Rinkinen, J., Juntunen, J.K., Tainio, P., Nissilä, H., 2017. Everyday experimentation in energy transition: A practice-theoretical view. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.03.034

Kaaronen, R.O., 2017. Affording Sustainability: Adopting a Theory of Affordances as a Guiding Heuristic for Environmental Policy. Front. Psychol. 8. https://doi.org/10.3389/fpsyg.2017.01974

Keller, M., Halkier, B., Wilska, T.-A., 2016. Policy and Governance for Sustainable Consumption at the Crossroads of Theories and Concepts. Environ. Policy Gov. 26, 75–88. https://doi.org/10.1002/eet.1702

Kokoni, S., Skea, J., 2014. Input–output and life-cycle emissions accounting: applications in the real world. Clim. Policy 14, 372–396. https://doi.org/10.1080/14693062.2014.864190

Kuijer, L., Bakker, C., 2015. Of chalk and cheese: behaviour change and practice theory in sustainable design. Int. J. Sustain. Eng. 8, 219–230. https://doi.org/10.1080/19397038.2015.1011729

Laakso, S., 2017a. Creating New Food Practices: A Case Study on Leftover Lunch Service. Food Cult. Soc. 1–20.

Laakso, S., 2017b. Giving up cars – The impact of a mobility experiment on carbon emissions and everyday routines. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.03.035

Laakso, S., 2017c. A practice approach to experimental governance: Experiences from the intersection of everyday life and local experimentation. Diss. Sch. Dr. Sci. Circumiectalis Aliment. Biol.

Laakso, S., Lettenmeier, M., 2016. Household-level transition methodology towards sustainable material footprints. J. Clean. Prod. 132, 184–191. https://doi.org/10.1016/j.jclepro.2015.03.009

Lyytimäki, J., Tapio, P., Varho, V., Söderman, T., 2013. The use, non-use and misuse of indicators in sustainability assessment and communication. Int. J. Sustain. Dev. World Ecol. 20, 385–393. https://doi.org/10.1080/13504509.2013.834524

Matuštík, J., Kočí, V., 2019. Environmental impact of personal consumption from life cycle perspective – A Czech Republic case study. Sci. Total Environ. 646, 177–186. https://doi.org/10.1016/j.scitotenv.2018.07.233

Mont, O., Heiskanen, E., Power, K., Kuusi, H., 2013. Lessons from Nordic Council of Ministers study "Improving Nordic policymaking by dispelling myths on sustainable consumption." Nordisk Ministerråd. https://doi.org/10.6027/NA2013-915

Mylan, J., 2015. Understanding the diffusion of Sustainable Product-Service Systems: Insights from the sociology of consumption and practice theory. J. Clean. Prod. 97, 13–20. https://doi.org/10.1016/j.jclepro.2014.01.065
Nahar, D., Verma, P., 2018. Shaping public behavior and green consciousness in India through the 'Yo!Green' Carbon Footprint Calculator. Carbon Manag. 9, 127–144. https://doi.org/10.1080/17583004.2018.1435960
Naus, J., Spaargaren, G., van Vliet, B.J.M., van der Horst, H.M., 2014. Smart grids, information flows and emerging domestic energy practices. Energy Policy 68, 436–446. https://doi.org/10.1016/j.enpol.2014.01.038
Nicolini, D., 2012. Practice Theory, Work, and Organization : An Introduction. OUP Oxford, Oxford.
Nissinen, A., Heiskanen, E., Perrels, A., Berghäll, E., Liesimaa, V., Mattinen, M.K., 2015. Combinations of policy instruments to decrease the climate impacts of housing, passenger transport and food in Finland. J. Clean. Prod. 107, 455–466. https://doi.org/10.1016/j.jclepro.2014.08.095
Padgett, J.P., Steinemann, A.C., Clarke, J.H., Vandenbergh, M.P., 2008. A comparison of carbon calculators. Environ. Impact Assess. Rev. 28, 106–115. https://doi.org/10.1016/j.eiar.2007.08.001
Peters, G.P., Hertwich, E.G., 2008. CO_2 Embodied in International Trade with Implications for Global Climate Policy. Environ. Sci. Technol. 42, 1401–1407. https://doi.org/10.1021/es072023k
Reckwitz, A., 2002. Toward a theory of social practices: A development in culturalist theorizing. Eur. J. Soc. Theory 5, 243–263.
Røpke, I., 2009. Theories of practice — New inspiration for ecological economic studies on consumption. Ecol. Econ. 68, 2490–2497. https://doi.org/10.1016/j.ecolecon.2009.05.015
Sahakian, M., Wilhite, H., 2014. Making practice theory practicable: Towards more sustainable forms of consumption. J. Consum. Cult. 14, 25–44. https://doi.org/10.1177/1469540513505607
Salo, M., Mattinen, M.K., 2017. Carbon footprint calculators for citizens, 2017:548. TemaNord. Nordic Council of Ministers, Copenhagen. https://doi.org/10.6027/TN2017-548
Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., Uotinen, M., 2016. Tailored advice and services to enhance sustainable household consumption in Finland. J. Clean. Prod. 121, 200–207. https://doi.org/10.1016/j.jclepro.2016.01.092
Schanes, K., Giljum, S., Hertwich, E., 2016. Low carbon lifestyles: A framework to structure consumption strategies and options to reduce carbon footprints. J. Clean. Prod. 139, 1033–1043. https://doi.org/10.1016/j.jclepro.2016.08.154
Schatzki, T.R., 2002. The Site of the Social : A Philosophical Account of the Constitution of Social Life and Change. Penn State University Press, University Park.
Schatzki, T.R., 1996. Social practices: A Wittgensteinian approach to human activity and the social. Cambridge University Press., Cambride; New York.
Seppälä, J., Mäenpää, I., Koskela, S., Mattila, T., Nissinen, A., Katajajuuri, J.-M., Härmä, T., Korhonen, M.-R., Saarinen, M., Virtanen, Y., 2011. An assessment of greenhouse gas emissions and material flows caused by the Finnish economy using the ENVIMAT model. J. Clean. Prod. 19, 1833–1841. https://doi.org/10.1016/j.jclepro.2011.04.021
Shove, E., 2017. What is wrong with energy efficiency? Build. Res. Inf. 1–11. https://doi.org/10.1080/09613218.2017.1361746
Shove, E., 2010. Beyond the ABC: Climate Change Policy and Theories of Social Change. Environ. Plan. A 42, 1273–1285. https://doi.org/10.1068/a42282
Shove, E., 2003. Comfort, cleanliness and convenience: the social organization of normality. Berg, Oxford.
Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice: Everyday Life and how it Changes. SAGE Publications.
Smale, R., van Vliet, B., Spaargaren, G., 2017. When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands. Energy Res. Soc. Sci. 34, 132–140. https://doi.org/10.1016/j.erss.2017.06.037
Spaargaren, G., 2011. Theories of practices: Agency, technology, and culture. Glob. Environ. Change 21, 813–822. https://doi.org/10.1016/j.gloenvcha.2011.03.010
Spaargaren, G., 2003. Sustainable Consumption: A Theoretical and Environmental Policy Perspective. Soc. Nat. Resour. 16, 687–701. https://doi.org/10.1080/08941920309192
Spaargaren, G., Lamers, M., Weenink, D., 2016. Introduction: using practice theory to research social life, in: Practice Theory and Research: Exploring the Dynamics of Social Life. Routledge, Taylor & Francis Group, London ; New York, pp. 3–27.
Spaargaren, G., Oosterveer, P., Loeber, A., 2012. Sustainability Transitions in Food Consumption, Retail and Production, in: Food Practices in Transition Changing Food Consumption, Retail and Production in the Age of Reflexive Modernity. Routledge, New York, pp. 1–31.

Spurling, N., McMeekin, A., Shove, E., Southerton, D., Welch, D., 2013. Interventions in practice: re-framing policy approaches to consumer behaviour.
Sutcliffe, M., Hooper, P., Howell, R., 2008. Can eco-footprinting analysis be used successfully to encourage more sustainable behaviour at the household level? Sustain. Dev. 16, 1–16. https://doi.org/10.1002/sd.327
Warde, A., 2016. The Practice of Eating. Polity Press, Cambridge.
Warde, A., 2005. Consumption and theories of practice. J. Consum. Cult. 5, 131–153.
West, S.E., Owen, A., Axelsson, K., West, C.D., 2016. Evaluating the Use of a Carbon Footprint Calculator: Communicating Impacts of Consumption at Household Level and Exploring Mitigation Options: Communicating Consumption Impacts to Households. J. Ind. Ecol. 20, 396–409. https://doi.org/10.1111/jiec.12372
Wiedenhofer, D., Guan, D., Liu, Z., Meng, J., Zhang, N., Wei, Y.-M., 2017. Unequal household carbon footprints in China. Nat. Clim. Change 7, 75–80. https://doi.org/10.1038/nclimate3165
Wiedmann, T., 2009. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. Ecol. Econ. 69, 211–222. https://doi.org/10.1016/j.ecolecon.2009.08.026

Links to calculator websites (accessed 28th January 2018)

Baltic Sea Card http://www.balticseaproject.org/en/calculator-page
Car comparison calculator http://calc.orkusetur.is/OrkuseturCalc/CarComparison/is
Climate Neutral Now http://climateneutralnow.org/Pages/footprintcalculator.aspx
CO_2-beregneren https://www.energitjenesten.dk/test-dit-co2-forbrug.html
Ducky https://www.ducky.no/
Ilmastodieetti https://beta.ilmastodieetti.fi/
Klimatkontot http://www.klimatkontot.se/
Kolvidur calculator http://kolvidur.is/carbon-calculator/
Min klimatpåverkan http://www.minklimatpaverkan.se/
REAP Petite (Min klimatpåverkan in UK) https://www.sei-international.org/reap-petite
WWF UK environmental carbon footprint http://footprint.wwf.org.uk/

Calculator features and user engagement	Type of feature or engagement	Name of the calculator: Baltic Sea Card *	Car comparis. calculator	Climate Neutral Now	CO2-bereg-neren	Ducky	Ilmasto-dieetti	Klimat-kontot	Kolvidur calculator	Min klimat-påverkan / REAP Petite	WWF UK environmen-tal carbon footprint
Collaboration with intermediaries (e.g. municipal sustainability experts, teachers, NGOs, event organisers) to reach users.	Recruiting users	?	no	yes	yes	yes	yes	yes	?	yes	?
Calculator used in community level research projects or campaigns, and combined with group or household meetings with experts.	Recruiting users / Support	?	no	no	no	yes	yes	yes	?	yes	?
Calculator provides supported and more detailed calculation alternatives. Supported option provides estimates or default values e.g. energy consumption based on size, whereas detailed options allow inserting real consumption data of energy or fuel.	Usability	no	yes	yes	no	no	yes	yes	no	yes	no
Calculation can be performed both at an individual and household level.	Usability	no	yes	yes	no	no	no	no	no	yes	no
Developers collect feedback from users e.g. in the form of spontaneous emails, an online questionnaire, phone and/or face-to-face interviews.	Usability	?	yes	yes	?	yes	yes	yes	?	yes	?
Calculator provides personalised estimates for consumption and footprint based on inserted data and preferences. Estimates are based on e.g. the type of housing, chosen energy sources, or dietary preferences.	Knowledge/ Usability	yes	yes	yes	yes	no	yes	yes	yes	yes	yes
Calculator takes into account and therefore makes visible low-carbon choices e.g. energy efficiency measures used at home, low-carbon energy use, buying second-hand items.	Knowledge	no	no	yes	yes	yes	yes	yes	yes	yes	yes
Calculator explains the role of consumption and policy measures on the local/national/international levels in mitigating climate change. The explanation is available on the calculator interface or in the documentation.	Knowledge	no	no	no	no	no	yes	yes	no	yes	yes
Calculator introduces the concept of a government footprint, i.e. the GHG emissions of public services.	Knowledge	no	no	no	no	no	no	yes	no	yes	yes
The total result (carbon footprint) is split by consumption categories to present the significance of each category.	Knowledge / Support	no	no	yes	no	no	yes	yes	no	yes	yes
Calculator has features that allow users to compare their own results (carbon footprint) with e.g. the national average, similar households, sustainable global level.	Knowledge / Support	no	no	no	no	yes	yes	yes	no	yes	yes
Calculator provides feedback and suggestions for taking action e.g. replacing carbon-intensive technologies with low-carbon alternatives, changing practices to save energy, or offsetting the emissions.	Support	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
Users can see personal progress e.g. the history of one's footprint results or number completed actions.	Support	no	no	no	no	yes	yes	no	no	yes	no
Calculator has a group feature to show the contribution of a certain group or the total contribution of the calculator users.	Support	no	no	yes	no	yes	yes	no	no	yes	yes

? Refers to missing data. We did not reach a representative for an interview and data was not available through the desktop study.

*Features listed for the Baltic Sea Card are based on the free version of the calculation framework on the website. It is possible that customers using the card have access to more specific features, although we were not able to confirm this.