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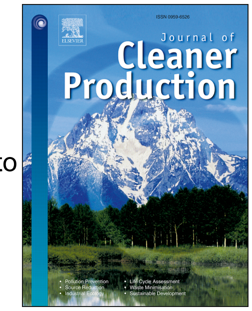

Low carbon lifestyles: A framework to structure consumption strategies and options to reduce carbon footprints

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Abstract

There are many opportunities for consumers to design their lives more sustainably. While a rapidly growing body of literature has investigated how consumers can reduce carbon footprints in key consumption areas, such as food, housing and mobility, an overall framework that allows structuring those options across all consumption areas is still missing. Hence, this paper presents a novel and systematic framework to identify improvement options that promote climate change mitigation and structure them based on their primary mode of impact on GHG emissions. The framework targets consumer practices and focuses on ambitious, but technically and socioeconomically feasible strategies for consumers to lower their carbon footprint. Four major categories for reducing consumption-based emissions form the basic framework, which are then subdivided into behavioral strategies and sub-strategies. The practical application of the framework is illustrated by using food consumption as an example. Systematically identifying improvement options can advance a holistic understanding of the range of behavioural strategies targeting consumer choices that operate at different stages in the supply chain. It thus provides a starting point for addressing critical questions related to the role of consumers in supporting climate change mitigation.

Key words

Climate mitigation, consumer behaviour, practices, food, sustainable consumption, sustainable lifestyles, carbon footprint

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1 Introduction

Climate change is perceived as a serious threat to the ecosystems on Earth as well as the future well-being of humanity. In order to meet the required substantial reductions in greenhouse gas (GHG) emissions, changes in consumption patterns are increasingly recognised as an important pillar to address the global climate change mitigation challenge and have also become increasingly relevant in recent policy debates. The mitigation report of the Intergovernmental Panel on Climate Change (IPCC) states that behaviour, lifestyle, and culture have a considerable influence on energy use and associated emissions and that stabilizing or lowering consumption, transitioning towards a sharing economy and adopting other behavioural changes have a high mitigation potential (Edenhofer et al., 2014, p. 20). In the European Union, the 'Roadmap for moving to a competitive low carbon economy in 2050' (EC, 2011a) and the 'Transport White Paper' (EC, 2011b) also acknowledge that behavioural changes may be needed to reach emissions targets and that targets may be reached at lower costs if behavioural changes are achieved. Different patterns of both consumption and daily life are therefore central to addressing the global mitigation challenge.

The rhetoric of individual empowerment and self-responsibility postulated by political agendas, as well as the new belief in public involvement, seem to indicate that the individual is increasingly regarded as a primary agent of climate change mitigation (Princen, 2002). Even if it is not clear whether individuals should be the key actors to pursue the transformation to a low carbon society, there seems to be a widespread consensus that also individuals need to alter their current consumption practices to tackle climate change. Apart from that assumption, however, there is less consensus on the definition of climate-friendly lifestyles, what they entail in terms of concrete changes in consumption and how far-reaching these changes need to be (Evans and Abrahamse, 2009). It is subject of debate whether those changes have to be incremental, practical and fit within peoples' current lifestyles or whether more fundamental and radical changes are needed (Jackson, 2011; Lorek, 2009; Thøgersen and Crompton, 2009).

Climate mitigation efforts related to consumption have primarily centred on shifting the goods people purchase towards options with lower impacts (Lorek and Spangenberg, 2014) and/or improving energy conservation practices (e.g. switching off lights when leaving a room or adjusting indoor temperature) (Clarke et al., 2014). However, in order to realize substantial reductions in emissions, it is crucial to think beyond well-known options and to seek new opportunities for emissions reduction (Allwood et al., 2011).

There are hundreds of specific actions people can undertake to "green" their lifestyles, as evidenced by the growing number of papers dealing with low-carbon lifestyles. In order to change behaviour in the right direction, it is in a first step important to first specify the target behaviour (Darnton and Horne, 2013). From the householder's perspective there are different behaviours to reach a policy goal such as 'to save energy in the home'. It can be realized e.g. by turning down the thermostat, and/or installing double glazing or solid wall insulation of existing buildings or buy moving to a passive house (Darnton and Horne, 2013). Different types of behaviours vary in their contexts and factors which influence their diffusion and each would need to be promoted in different ways. It is first of all critical that the differences between varying behaviours is clear to get further insights in both the environmental impacts of them but also the factors that facilitate or impede their uptake.
From an industrial ecology perspective, the disaggregation of these behaviours into specific mitigation strategies helps to structure consumer practices and can serve as a starting point for calculating the emission-saving potential of different strategies in order to gain more insight into the effectiveness of specific measures. Most behavioural studies focus predominantly on consumers' levels (quantity) of performing sustainable behaviours, while empirical research on the distinctions between different types (quality) of behavioural strategies that consumers perform is still lacking (Verain et al., 2015).

Disaggregation can hereafter help to further stimulate empirical research on the factors that encourage or discourage a range of different behaviours and thereby provide a more comprehensive understanding of climate-friendly behaviours. Based on the identified strategies, it is possible to distinguish between various consumer segments and address them with different communication strategies. Hence, the categorisation that we elaborated is supposed to steer further research on the effectiveness of different behaviours, as well as factors that drive or impede their uptake has not yet been researched systematically.

Some attempts have been made to classify consumer options, but a consistent and comprehensive framework is still missing. Given the emergence of behaviour and lifestyle changes on political and academic agendas and disagreements over the efficacy of individual actions, this paper presents an innovative and comprehensive framework that allows for consistently structuring the manifold consumer actions. The framework is focuses on the circumstances in industrialized countries, with the European Union as a concrete example.

As a result, the framework provides both academics and policymakers with new insights into the utility of distinguishing between different consumption strategies and including strategies from various approaches as a differentiated instrument for climate change mitigation. The ambition of this paper is therefore practical: to survey the wide range of options for final consumers; to clarify and organize those options based on their different scales and depths of change and primary mode of impact on GHG emissions and to identify the key options for the example domain of food consumption to stimulate their implementation.

The remainder of this paper is structured as follows. Section 2 provides a more detailed description of the applied methodology. Section 3 highlights and describes the framework's main strategies and sub-strategies that tend to be essential in consumer-oriented mitigation of carbon emissions. Moreover, the chapter discusses strengths and weaknesses of these strategies on the basis of selected examples from the literature. Section 4 illustrates how the framework can be used to present the most promising mitigation options for the example consumption area of food. Finally, the conclusions of this research are presented in Section 5.

2 Methodology

To analyse which consumer practices and actions are most effective for lowering carbon footprints, we started with a comprehensive literature review on existing consumer options with the potential to reduce GHG emissions. The research process was iterative. In total, we analysed more than 100 documents including journal articles and policy documents (IPCC, OECD, European Commission, UNEP) with an explicit focus on sustainable consumption or production (SCP). Based on the reviewed literature, we developed preliminary codes using qualitative content analysis as well as a thematic analysis (Mayring and Fenzl, 2014). The analysis led to the formulation of analytical categories which helped to structure the consumer options and ensured an empirically grounded categorization of the consumer options into key mitigation strategies and sub-strategies. The categorization was selected deductively based on characteristics of the behaviours themselves, their differences in scale and type of change, their location in the consumer centred stages of the supply chain (acquisition, use, disposal) and their primary mode of impact.

Many of the strategies we consider in our framework are already included in existing attempts to distinguish between different consumer options. For example Girod et al. (2014) identified possible strategies to lower GHG emissions by applying the IPAT equation. This approach provides detailed insight regarding possible consumer strategies to lower their impact. The two overarching categories improvement and reduction are similar classifications that have already been applied in the past e.g.

by Christoff (1996), who used the terms weak and strong ecological modernization. The former is characterized by an economic perspective and mainly refers to technological solutions and the latter supports a more ecological logic that involves broad changes to institutional and economic structures of society. Furthermore, Fuchs and Lorek (2005) differentiate between weak and strong sustainable consumption. ‘Weak’ forms of sustainable consumption intervention focus on efficiency and technological innovation. By contrast ‘strong’ forms of sustainable consumption displace current foci of ‘growth’ by a stronger orientation on frugality and sufficiency. A more recent paper by Geels et al. (2015) uses the terms reformist and revolutionary position.

However, compared to existing framings, our paper defines more specific categories of behaviour than the broad construct of efficiency and sufficiency behaviour (Lorek and Fuchs, 2013; Mont and Plepys, 2008). The central elements of this framework originate from key concepts such as ‘collaborative consumption’ (Botsman and Rogers, 2010) or ‘connected consumption’ (Schor and Fitzmaurice, 2015), circular economy (EC, 2015), material efficiency (Allwood et al., 2013), prosumption (Ritzer et al., 2012) and finally strong and weak sustainable consumption (Fuchs and Lorek, 2005). Apart from that, we implemented a stronger distinction between strategies that reduce use phase (direct) versus production phase (embodied) emissions. With respect to the production side, the framework distinguishes between three different efficiency strategies that need to be improved along the upstream parts of the supply chain in order to provide more efficient products for consumers. Finally, the framework includes a higher disaggregation of the various strategies than the one completed by other authors.

This broader perspective creates a more nuanced and holistic array of strategies. Besides that, the proposed framework takes a more GHG emissions-centred view on strategies and primarily focuses on consumers. As a result, the more precise subdivision provides a detailed overview of the plethora of strategies and possible effects on both direct and embodied emissions.

3 Framework for mitigation strategies and options for consumers

Consumption affects the environment through daily actions and practices. Different consumer practices can cause variable amounts of GHG emissions. Consumer behaviour beyond purchase decisions is recognized as a critical requirement in the quest for sustainable consumption (Jackson et al., 2004; Jacobs and Røpke, 1999). The size of the individual and collective footprint is a function of both the quantity and the characteristics of the goods and services, and from a combination of product-use (lifetime) and product end-of-life treatment (Mont and Heiskanen, 2015; Princen, 2002).

- **Acquisition:** Although within limits, consumers can exercise a choice between buying a more sustainable product, sharing/renting/leasing/borrowing a product or not purchasing a product. Within this decision, consumers can use their action power as citizens and voters to trigger more sustainable behaviour in the supply chain (O’Rourke, 2014).
- **Product use**: Consumers can use products instead of buying them (Schor and Fitzmaurice, 2015) and they can extend the lifetime of products by using products for their full useful life by, e.g., repairing, maintaining, upgrading or exchanging defective parts of goods (Cooper, 2005, 2012).
- **Product end-of-life treatment**: When products have reached the end of their useful life, consumers have different options for waste disposal, allowing them to deal with waste in a more efficient manner e.g. a re-direction of waste from landfill to recycling and reuse (Prognos, 2008).

All consumption activities cause direct and/or embodied emissions. Direct emissions stem from final consumption activities like GHG released when homes are being heated or automobiles are moving. The carbon footprint of a product indicates the amount of GHGs emitted within its entire lifecycle

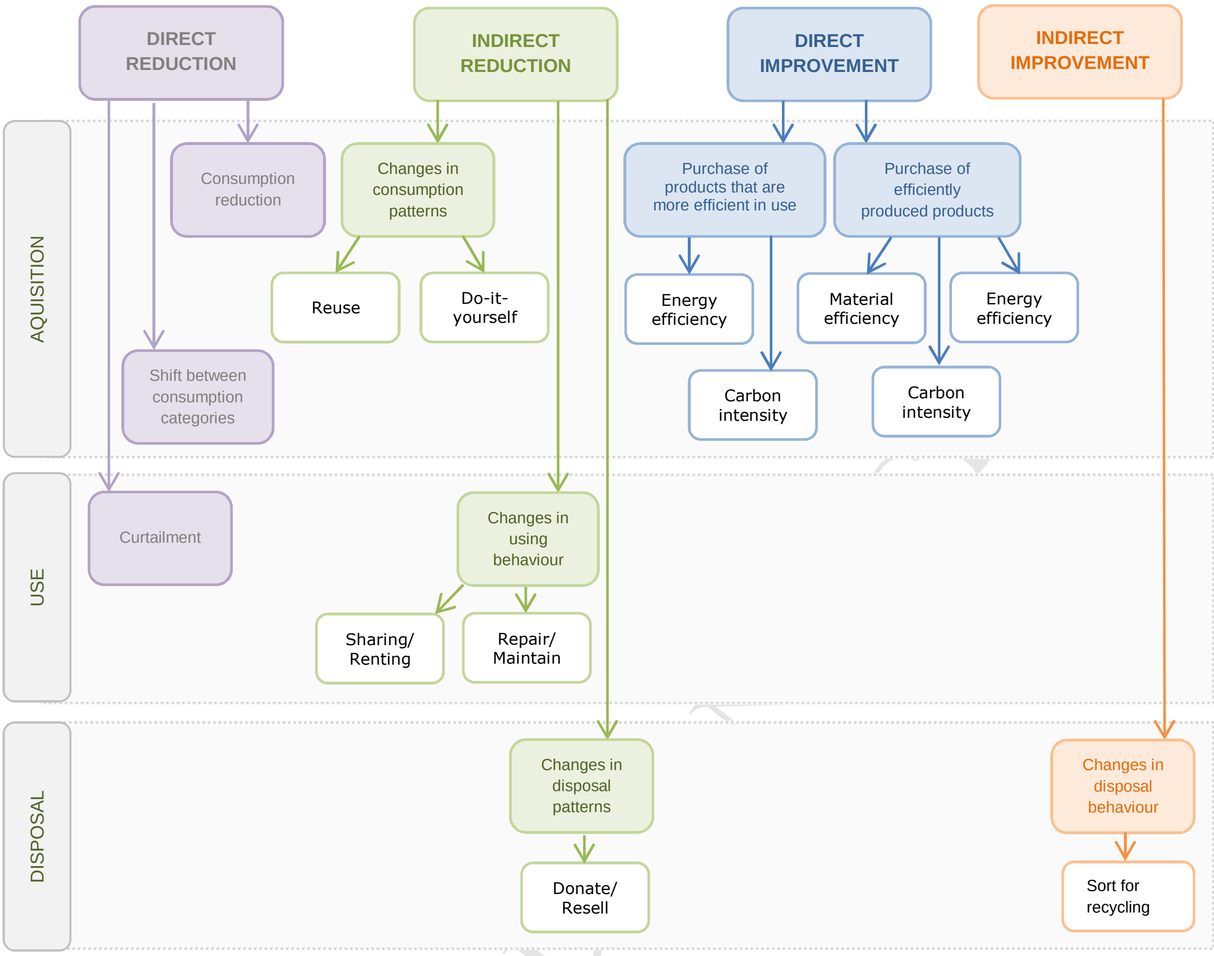
(Wiedmann and Minx, 2007). The large body of literature on consumer improvement options so far focused almost entirely on direct emissions (Deetman et al., 2013; Girod et al., 2013). However, consumption practices in developed countries cause huge embodied emissions that are embodied in products and that occur in upstream parts of the supply chain during resource extraction, processing, manufacturing and packaging, storage and transportation (Hertwich et al., 2010; Hertwich, 2011). The impact of consumer behaviour on embodied emissions has so far received insufficient attention, but may have a significant untapped potential for climate change mitigation (Weber and Perrels, 2000). Given that embodied emissions are more important than direct emissions in determining the carbon footprint of households (Hertwich and Peters, 2009) we particularly include strategies and options to reduce this emission type. Looking at consumer options and analysing their impact on upstream supply chain emissions i.e. from resource extraction to final waste disposal could therefore contribute to a more holistic realization of life cycle thinking and influence how impacts from consumption are analysed and addressed (Mont and Bleischwitz, 2007).

The role of consumers and their potential scope for action towards mitigating climate change has been vividly discussed in the literature (Darnton et al., 2011; Geels et al., 2015). Therefore, thoroughly considering how different academic disciplines perceive behaviour change is beyond the scope this paper. However, it is assumed that consumers do not possess full control over their actions and are not empowered to change their practices while existing systems and institutions remain (largely) unchanged. Their practices are for a large part shaped by infrastructures, social norms and habits that limit the ability to act independently to exercise free choices (Shove and Walker, 2010). Ultimately, effective implementation will depend on structural changes and collective efforts from a combination of producers, government as well as from consumers (Tukker et al., 2008).

In the following section, we present an innovative conceptual framework that includes effective strategies and sub-strategies for end-users to mitigate direct emissions as well as emissions embodied in products. Basically, the framework is divided into the two overarching categories of improvement and reduction. The basic concepts underlying these two terms exhibit marked differences on scales, depths and type of change that is needed to mitigate climate change. Under the heading of improvement, change is triggered by technological innovations of producers that provide more efficient products and consumers that buy them. On the contrary, under the umbrella of reduction, strategies are subsumed that advocate non-consumption concepts and practices such as reductions in consumption levels and lifestyle changes. Within the presented framework, we identify four major strategies, or broad lines of action, and split them further into nine different mitigation sub-strategies. Sub-strategies are a diverse set of specific behaviours which are identified as an efficient and effective means of reducing carbon emissions.

Figure 1 presents the framework and the corresponding strategies and sub-strategies. The following chapter provides a short overview of the main elements of the framework and explores each of the strategies in more detail. The main environmental arguments of the strategies are highlighted in Table 1 together with possible adverse effects that are likely to occur.

Figure 1: Framework for mitigation strategies and sub-strategies



3.1 Direct reduction

In order to realise deep cuts in carbon emissions, consumption level restraint in richer nations is considered a legitimate climate mitigation option (Druckman and Jackson, 2010). The consumption reduction perspective is based on the conviction that the overall level of consumption is the root cause of the current environmental crisis and that further growth in affluence and related overconsumption does not increase personal wellbeing (Jackson, 2011). By extension, some argue, that there is a need of replacing the focus on growth with 'de-growth' in order to allow the global poor a larger share of our limited resources (Kallis, 2011). Apart from research, numerous initiatives promote a simpler lifestyle. Examples include the 'voluntary simplicity' movement (Ballantine and Creery, 2010) or the 'downshifting' movement (Hamilton, 2010). All these lifestyle movements share a common emphasis to displace current foci of 'growth' and consumerism to a stronger orientation on frugality and sufficiency and improved well-being (Jackson, 2011).

In terms of direct reduction within the context of this paper, we distinguish between three types of demand reduction. The first is consumption reduction, which means a decrease in the amount of products and services purchased, for example through buying less clothes or reducing living space. The second, which entails a shift between consumption categories and a redirection of household expenditure from categories with the highest GHG intensities (e.g. mobility) to less GHG intensive consumption categories (e.g. cultural and recreation activities or education) also falls under the broader category of direct reduction (Ivanova et al., 2016; Jackson, 2011).

The third curtailment, refers to frequent and/or low cost (or even cost-saving) energy-saving behaviours in the use phase of products. In other words, it refers to using existing products in a more efficient way (e.g. low carbon driving style), using products less frequently (e.g. turning off lights when leaving rooms) or with less energy input in order to reduce the associated emissions (for instance reducing ambient room temperatures, cooking or laundering temperatures).

In contrast to improvement strategies, consumers do not buy additional products that reduce use phase emissions, but rather change their using behaviour accordingly. Accordingly, reduction strategies require a more fundamental change within daily life practices.

It appears that reducing the overall demand for products or services is highly effective in reducing emissions. This includes reductions in the unnecessary consumption of products, less travel and lower heating demand (Druckman et al., 2011). Still, there is little empirical evidence that the identified kinds of shifts in behaviour would lead to a significantly reduced emissions or a happier society. Moreover, it is important to stress that even if there are no direct rebound effects when the consumer has voluntarily chosen to consume less of a specific good or service, options under this heading may lead to indirect rebound effects which will lower the environmental benefits of the relevant action (Druckman et al., 2011; Sorrell, 2007). It is assumed that the avoided expenditure due to these actions is either re-spent on other goods and services or is saved. Savings will also be associated with GHG emissions as they may end up in deferred consumption or as a source of funds for investment (Chitnis et al., 2013).

Research also reveals that, although reduction of consumption generally requires no financial outlay, consuming less proves to be much more difficult – even for aware, interested, and committed individuals (Isenhour, 2010). The most important barriers mentioned with regard to consuming less can be classified as problems of sociality. Consumption is a major component of shared societal and cultural norms and can contribute to a sense of belonging. Other barriers to consuming less include the difficulty of establishing everyday routines and habits and concerns with equality and fairness (ibid.). Moreover, consumption reduction is hampered by prevailing economic and political forces that emphasize efficiency and 'win-win' outcomes in which environmental and economic benefits are produced simultaneously, while claims to consume less remain unconsidered. It becomes obvious that consuming less is not only a question of changing individual behaviour, but changing whole systems of economic, technological and social practices (Urry, 2010).

3.2 Indirect reduction

The second category entitled indirect reduction aims at indirectly reducing emissions through alternative approaches to acquiring, using and disposing products (and services). They are linked with far-reaching changes in daily practices and/or organisational structures. Sub-strategies under this heading are: sharing and renting products and services (increased utilization of durable assets), reuse and donate and resell (recirculation of goods), repair (extend product life) and do-it-yourself (own production of goods and services).

Sharing, swapping, bartering, trading or renting products as opposed to ownership are often summarized under the terms Collaborative Consumption (Botsman and Rogers, 2010) or Sharing Economy (Hinterberger et al., 1994; Schor, 2014). In Product Services Systems (PSS), that represents one category of Collaborative Consumption, the traditional product still plays a central role, but ownership of the product remains with the provider, it is made available in different forms, and it is sometimes shared by a number of users. Subcategories are product leasing (use by a single user), product renting or sharing (sequential use by different users), or product pooling (simultaneous use of the product by various users, e.g. carpooling) (Tukker, 2013). Examples for renting are among others Zipcar, fashion and toy rental, laundries and libraries. It is assumed that firms will have an incentive to prolong the service life of products, to ensure they are used as intensively as possible, to make them as cost- and material-efficiently as possible, and to re-use parts as far as possible after the end of the product's life (Tukker, 2013). There are also private or community based exchange opportunities like swapping and bartering that happen between individuals and often involve products such as clothes, tools or books.

Communal use of products and business models in the area of sharing and renting intend to facilitate using durable goods and other assets more intensely, so that the total demand for services can be met with fewer new goods. The environmental benefit of using products more intensely is expected to come from decreased demand for products, that will therefore reduce the indirect emissions arising during resource extraction, manufacturing and disposal. More intensive use can balance the environmental trade-offs between product life extension and technological obsolescence (Skelton and Allwood, 2013). In the case of car sharing, direct emissions could be decreased if either the overall km driven are reduced through sharing and not owing a car or if the car that is shared is fuelled by lower carbon intensive fuels (Martin and Shaheen, 2011).
However, a review of collaborative consumption activities shows a mixed potential. The outcome of some studies may give a short insight in the mixed result of the environmental (dis)advantages of sharing, renting and leasing. A life cycle optimization analysis of two product categories (household appliances and computers) compared leasing with product sales. The results indicate that product leasing closes material loops, promotes remanufacturing or recycling, and sometimes leads to shorter life cycles. It is argued that products with high use impacts and improved technology can benefit from reduced life cycles (achieved through product leases), whereas products with high manufacturing impacts and no improving technology do not (Intlekofer et al., 2010).

A study from North America also highlights the decrease of GHG emissions from transportation due to car-sharing. Results suggest that car-sharing facilitates large reductions in the annual emissions of some households, which compensate for the collective small emission increases of other households. The results also show that respondent households exhibit significant reductions in vehicle ownership after joining car-sharing (Martin and Shaheen, 2011).

A report by the Waste and Resource Action Programme (WRAP) explores new, innovative business models of clothing retailing. The authors come to the conclusion that large-scale leasing of baby clothes is, second to the peer-to-peer exchange of garments on online platforms, the most effective from a carbon impact perspective with the largest amount of saving of garments going to waste (WRAP, 2013).

In sum, it can be concluded that sharing activities are not by definition the most GHG saving practices. They could potentially intensify the use of products and hence could reduce the need for new products. However, a possible drawback is that they often lead to less careful user behaviour since the consumer no longer owns the product and this fact could lead to higher impacts (Tukker, 2013).

By contrast, reuse, repair and donate and resell seek to prolong and/or optimize the product life. On the one hand, reuse strategies, where pre-owned and unused goods are sold and bought on redistribution markets (e.g. Flea markets, charity shops, freecycle) can contribute to emission savings by providing an alternative to purchasing new items and reduce waste and tend to lead to extended lifespans of products (Kay and Essex, 2009; WRAP, 2011a, b). On the other hand repair and maintenance are responses to early failure of parts or components within a product. For certain product groups people can repair them by themselves (e.g. clothes), other repair activities will require a tradesman with specialist knowledge to complete the repair (e.g. cars). Both strategies aim to reduce the amount of emissions associated with the production of new goods. Barrett and Scott (2012) revealed a considerable potential for reducing emissions if consumers use products for the entirety of their useful life and increase product life through repair and maintenance. Nevertheless, this is only the case if the reused item is not replaced by a new one (Farrant et al., 2010). From an environmental perspective it is clear that increasing product lifespans is essential, in particular for products in which upstream supply chain impacts dominate over the life cycle, e.g. construction materials, textiles and furniture (Devoldere et al., 2009; Dewulf and Duflou, 2004; Van Nes and Cramer, 2006). However, the reuse of products with high operating phase energy consumption, such as washing machines and refrigerators, can result in even higher total environmental impacts than the purchase of a new item because product performances often improve over time, which in turn leads to a more efficient use phase of products (Devoldere et al., 2009). Hence, although increasing product life allows the embodied emissions in products to be spread across a longer period, opportunities to improve use phase efficiency can be foregone (Skelton and Allwood, 2013). Therefore, the balance between durability and energy efficiency needs to be determined. Moreover, the potential would remain untapped if products are built to last longer and households continued to dispose of these products whilst they are still working.

Active consumership movements such as do-it-yourself (Watson and Shove, 2008) and craft consumption (Campbell, 2005) where consumers start bottom-up processes of collaborative production have gained public attention and have increasingly found approval in the domains of food, textiles and most importantly in the local co-production of renewable energy for space and water heating (e.g solar energy from solar panels on rooftops) (Panwar et al., 2011). In sustainability research, these new strands, in which consumers act as prosumers (combination of production and consumption) (Ritzer et al., 2012) are considered as promising for fostering a more sustainable lifestyle. However, their effect on GHG emissions has not yet been properly investigated except for domestic production of renewable energy.

Indirect reduction may be criticised because system reconfiguration and the profound changes that are required to transform current consumption practices may not deliver emissions reductions at the required speed. Furthermore it can be argued that the up-take and diffusion of the process takes too long.

3.3 **Direct Improvement**

Direct Improvement is a strategy, by which mitigation is achieved by more efficient forms of consumption. In other words, improvement strategies aim to encourage individuals to consume improved products and services that contain lower embodied and/or cause lower use phase emissions. It is intended to improve the environmental performance of products and services and alleviate negative impacts that occur along the supply chain through different purchase practices. Increasing the efficiency of consumption can be achieved either through (1) 'Purchase of efficiently produced products and services' (contain lower embodied emissions), and through (2) 'Purchase of products and services that are more efficient in use' (cause lower use phase emissions).

Concerning purchasing of efficiently produced products and services, three main product groups could be selected: products with (a) a reduced carbon intensity (produced with a lower-carbon content through the use of near-zero carbon energy sources such as renewables in the production process) (Grübler and Nakićenović, 1996), (b) enhanced energy efficiency (products that are more energy efficient due to new and more efficient processes and technologies along the supply chain) (Riahi et al., 2012), and (c) with increased material efficiency (products with a reduced material use) (Allwood et al., 2013). Material efficiency is expected to be achieved by many technical strategies including designing products for recycling/reuse/repair/upgrade, re-using and recycling components from unwanted products or designing products with less material through light-weight design or dematerialization (Allwood et al., 2013). Owing to the high energy intensity of materials extraction and production processes, a reduction of the overall material use would lead to less energy demand for mining, processing and transportation of raw material (UNEP, 2013) and consequently to a reduction in greenhouse gas emissions (IEA, 2015). Current efforts in climate mitigation mainly focus on enhancing energy efficiency and carbon intensity (Allwood et al., 2011). Allwood et al. (2013) state that the remaining options for efficiency improvement processes in those two domains are largely exhausted or cannot be implemented as quickly as required to meet the very ambitious emissions reductions targets proposed by climate scientists. The idea of ‘material efficiency’ or ‘resource efficiency’ in climate mitigation debates are supposed to add to pursuing energy and emissions efficiency (Allwood et al., 2013; Werland et al., 2015).

In addition to buying products and services which are more efficiently produced and thus have lower embodied emissions, consumers can purchase products that are more efficient in use, and thus reduce the arising use phase emissions. Products that are more efficient in use can be further dividend into energy efficient products that save emissions during the use phase (e.g. energy-efficient light bulbs) and less carbon intensive products, such as battery electric cars, that can use renewable energy sources.

Policy instruments such as eco-labels, information campaigns, taxes and subsidies are expected to encourage and incentivize consumers to change their behaviour in favour of low carbon products. However, for consumers especially, the impacts that occur in the upstream stage of the supply chains of products may be unknown or invisible (Grunwald, 2010). Information on the efficiency of production is often not transparent enough or simply not available to final consumers. Even if labels are in place, it appears that there is a general confusion and misunderstanding around carbon labelling among consumers. While consumers want to be in a position to make low carbon choices, they do not feel empowered to do so (Gadema and Oglethorpe, 2011).

However, while shifting consumer preferences to low GHG products is certainly very significant, what is equally important is that more efficient alternatives are available, affordable and attractive. The provision of low carbon products has to be realised by producers or retailers. What is needed is an integrated approach that targets both the supply chain - where producers realize opportunities to make sustained improvements to the environmental performance of their products- and the demand side.
Despite the approval and importance within prevailing policy debates, improvement strategies are subject to criticism (e.g. Jackson, 2011). Particularly, concerns are raised that incremental changes in the organization of production, consumption and institutional arrangements will not be sufficient to address the scale and urgency to meet ambitious climate targets (Lorek and Spangenberg, 2014). In contrast to ‘Direct reduction’ strategies, they do not focus on the physical limits of the economy in absolute terms and do not address overconsumption, but place all hopes on ‘win-win’ solutions that are supposed to combine environmental and economic benefits.

In addition, when efficiency improvements are implemented, they reduce the effective price of energy services such as travel, potentially resulting in a growth of overall fuel consumption, and thereby offsetting some of the expected reduction in energy consumption. An example of this so-called *direct* rebound effect can be found if consumers replace a car with a more fuel-efficient model and the cost savings from decreased running costs may incentivize more driving. By contrast, *indirect* rebound effects occur if the saved money is spent on other goods and services (e.g. leisure, clothing) that also require energy and GHG emissions to provide. While direct reduction strategies are only affected by indirect rebound effects, direct improvement strategies are affected by both direct and indirect rebound effects (Druckman et al., 2011).

3.4 **Indirect Improvement**

The fourth strategy refers to the indirect improvement of the GHG performance of products stemming from final consumers separating recyclable or reusable waste at the end of a product’s life. Formal collection systems and the use of take-back opportunities from retailers are possible routes for no longer required products.The positive effect on GHG emissions, however, is only realized when producers actually use secondary materials instead of primary materials as inputs for production. Recycling is applied especially for materials such as iron and steel, aluminium, glass, textiles, wood, paper/cardboard, and bio waste (BIOIS, 2011). Although recycling can be energy intensive, increased recycling rates can be an effective option for significant contributors to GHG reductions as well as resource savings and in most cases is still more energy efficient than mining and processing primary materials (Morley et al., 2009; Prognos, 2008). The mitigation potential also depends on the energy mix used in recycling process.

However, recycling should be the less preferable option and only deployed if more favourable options, such as re-use and repair, are not feasible (WRAP, 2011a, b). Reusing reclaimed materials or material components is also a promising solution for reducing embodied emission especially for highly carbon intensive materials such as metals and steel and aluminium components (Allwood et al., 2010; Cooper and Allwood, 2012). Recycling has already contributed significantly to emission savings, especially in European countries like Austria and Germany, while in many other European countries, like Greece, Spain, and Croatia there is still a high effort needed in order to achieve the target of 50% recycling of some municipal waste streams by 2020 (EEA, 2013b). On the contrary, reuse strategies have not yet received the attention they deserve (Allwood et al., 2011).

Table 1: Mitigation strategies and sub-strategies and resulting impacts on GHG emissions

	Improvement strategy	Sub-strategy	Main environmental argument	Problems
Direct Reduction	CONSUMPTION REDUCTION	-	*Decrease in embodied emissions* Smaller product stock *Decrease in direct emissions* Smaller product stock Less energy use	- Compensation with other more GHG intensive products and services
	CURTAILMENT	-	*Decrease in direct emissions* Less energy use	- Indirect rebound effect
	SHIFT BETWEEN CONSUMPTION CATEGORIES	-	*Decrease in embodied emissions* Smaller product stock *Decrease in direct emissions* Smaller product stock Less energy use	- Additional transportation
Indirect Reduction	CHANGES OF CONSUMPTION PATTERNS	Reuse	*Decrease in embodied emissions* Lifetime extension Smaller product stock	- Additional consumption - Additional transportation - Trade-offs due to more use phase efficiency improvements of new products
		Do-it-yourself	*Decrease in embodied emissions* Decrease of energy intensive production processes *Decrease in direct emissions* *Lower carbon intensity of electricity and power (e.g. solar panels)*	- Additional transportation
	CHANGES IN USING BEHAVIOUR	Sharing/ Renting	*Decrease in embodied emissions* Smaller product stock *Decrease in direct emissions* More efficient technology (e.g. cars)	- Additional consumption - Additional transportation - Excessive wear through more intensive use (shortened lifetime)
		Repair/ Maintain	*Decrease in embodied emissions* Lifetime extension Smaller product stock	- Additional consumption - Additional transportation - Trade-offs due to use phase efficiency improvements of new products (e.g. newer and more efficient washing machines, cars etc.)
	CHANGES IN DISPOSAL PATTERNS	Donate/ Resell	*Decrease in embodied emissions* Lifetime extension Smaller product stock	- Additional consumption - Additional transportation - Trade-offs due to use phase efficiency improvements of new products (e.g. newer and more efficient washing machines, cars etc.)
Direct Improvement	PURCHASE OF EFFICIENTLY PRODUCED PRODUCTS	Material efficiency Energy efficiency Carbon intensity	*Decrease in embodied emissions* More efficiently produced	- Rebound effect - Single action bias
	PURCHASE OF PRODUCTS THAT ARE MORE EFFICIENT IN USE	Energy efficiency	*Decrease in direct emissions* More efficient technology	- Direct and Indirect rebound effect - Additional consumption
		Carbon intensity	*Decrease in direct emissions* Cleaner technology (green electricity and power)	- Direct and Indirect rebound effect - Additional consumption
Indirect Improvement	CHANGES IN DISPOSAL BEHAVIOUR		*Decrease in embodied emissions* More efficient waste management	- Single action bias

4 Consumer options fostering a low carbon food consumption

After having introduced the framework, its practical application shall now be illustrated by examining food as an exemplary consumption area. A large number of studies have assessed the relative contributions of consumption options to environmental sustainability and GHG emissions. Those focusing on climate impact all indicate that food, mobility and housing are the categories that consistently make up the largest shares of GHG emissions (for example, EEA, 2013a; Hertwich and Peters, 2009). Especially in the domain of food, there is a large variety of potential consumer options to reduce GHG emissions and foster more sustainable food consumption, most of which are still largely untapped (Barrett and Scott, 2012). The most important consumer options for the consumption area of Food are listed in Table 2. Although a large evidence base exists regarding the advantages of more sustainable food patterns, political measures and strategies that encourage them are still rare and mainly limited to soft demand-side measures such as awareness campaigns (e.g. Love food hate waste), labelling and information platforms. However, to achieve the desired decreases in emissions, more stringent measures like the abolishment of subsidies on GHG intensive food, stronger regulations and economic incentives combined with softer measures tend to be more effective (Priefer et al., 2016).

Table 2: Mitigation options in the consumption category of food

	Improvement strategy	Sub-strategy	Examples for specific actions
Direct Reduction	CONSUMPTION REDUCTION	-	Avoid meat (vegetarianism , veganism and flexetariarism) Eat less meat (one meat-free day a week, eating smaller portions of meat Reduce over-purchasing and avoidable food waste Eat less (no more than needed to maintain a healthy body) Consume fewer foods with low nutritional value e.g. alcohol, tea, coffee, chocolate
	CURTAILMENT	-	N/A
	SHIFT BETWEEN CONSUMPTION CATEGORIES	-	Shift from spending money on food to e.g. cultural activities or education
Indirect Reduction	CHANGES OF CONSUMPTION PATTERNS	Reuse	Reuse unavoidable food waste directly for animal feed, as fertilizer and/or compost
		Do-it-yourself	Grow your own food, Community gardening, Community supported Agriculture
	CHANGES IN USING BEHAVIOUR	Sharing/ Renting	Food sharing
		Repair/ Maintain	N/A
	CHANGES IN DISPOSAL PATTERNS	Donate/ Resell	Food sharing
Direct Improvement	PURCHASE OF EFFICIENTLY PRODUCED PRODUCTS	Material efficiency	Purchase food that would otherwise be thrown away (funny carrots, close-to-expiry-date produce)
		Energy efficiency	Choice of lower carbon intensive alternatives within the same product group e.g. changing from GHG-intensive meats (ruminants) to less intensive meats (pork and poultry) Substitution of meat and dairy products by plant proteins Substitution of meat products by insects Purchase of seasonal food Purchase of food that is more efficiently produced (e.g. less fertilizer)
		Carbon intensity	Purchase of food that is produced in unheated greenhouses Purchase of food that is produced in biomass heated greenhouses
	PURCHASE OF PRODUCTS THAT ARE MORE EFFICIENT IN USE	Energy efficiency	N/A
		Carbon intensity	N/A
Indirect Improvement	CHANGES IN DISPOSAL BEHAVIOUR		Collect unavoidable food waste separately (use for animal feed, as fertilizer, compost, or to recover energy from anaerobic digestion

Under the heading of direct reduction, some potential lies in reducing the overall level of food consumption (Vieux et al., 2012) as well as of foods with low nutritional value, such as alcohol, tea, coffee or chocolate (Garnett, 2011). This would imply that people eat no more than is needed to maintain a healthy body. What is unchallenged is the fact that all final consumers need to dramatically reduce post-consumer food waste. Numerous studies point to the fact that food waste is an important issue related to reducing emissions (Hoolohan et al., 2013; Papargyropoulou et al., 2014). An important pathway to reduce diet-associated emissions is the reduction of consumption of high emission food categories. There is a broad consensus that meat avoidance is one of the most important recommendations for decarbonizing food consumption patterns (Stehfest et al., 2009). Decreasing meat portion size and reducing the frequency of meat eating can help minimize food-related emissions. An extreme form of meat consumption reduction is vegetarianism and veganism, which has by far the largest consumer-oriented reduction potential regarding embodied GHG emissions in the food sector (Berners-Lee et al., 2012; Carlsson-Kanyama and González, 2009).

The category of direct improvement offers a huge array of options for consumers to lower the impact of food consumption. A large number of scientific papers have provided mounting evidence of the environmental benefits of substituting meat products with lower carbon intensive alternatives within the same product group, like changing from GHG-intensive meats (ruminants) to less intensive meats (pork and poultry) (Hoolohan et al., 2013; Scarborough et al., 2014). More recently, some researchers have examined the mitigation potential of the substitution of dairy products (milk, cheese, eggs) by plant proteins and recognized this option as viable for reducing GHG emissions (Westhoek et al., 2014). A shift, even partially, from conventional livestock to insects is supposed to achieve much greater quantities of animal protein production with a much lower carbon footprint (Tabassum et al., 2016). The limited quantitative information on the benefits on insect consumption that is presently available although provides insufficient documentation of its effectiveness and is not free from uncertainties and challenges (ibid.).

While the effects on GHG emissions are quite straightforward for the options mentioned above, the proposition that local consumption will reduce the carbon footprint of food is not straight-forward when considering how the carbon intensity of food production varies widely across regions and can therefore outweigh the benefits of saved transport emissions (Avetisyan et al., 2014). This holds true also for the consumption of seasonal food, which is an activity that has gained increasing attention within climate-smart food consumption in the past years. ‘Eating seasonally’ has also increasingly been encouraged by government initiatives and supported by other agencies and organisations (Brooks et al., 2011). From a climate perspective, however, the environmental impact varies by the applied definition (globally vs locally seasonal). Greenhouse gas emissions of globally seasonal food are not necessarily higher than food produced locally as the total emissions depend to a higher degree on the production system and cropping pattern used than on transportation (Macdiarmid, 2014). The focus on food that is produced in unheated greenhouses or heated with renewable energy tends to be preferable (ibid). Eating more seasonal food is therefore only one element of a sustainable diet and should not overshadow some of the potentially more environmentally effective options like reducing overconsumption, food waste and meat consumption (Hoolohan et al., 2013).

In addition, especially in United States, there is a remarkable upswing of community gardening and a trend towards self-growing food (Lawson, 2005). Several studies have attempted to assess the benefits of community-supported urban agriculture projects in the UK, pointing especially to the social and economic advantages (Quayle, 2008). Quantitative evidence of the mitigation effects of self-grown food or community-based agriculture is almost entirely lacking and the effectiveness of such endeavors is not yet confirmed. However, one recent study showed that urban food supply systems can engender considerable reductions in GHG emissions that are potentially larger than those from parks or urban forests, by substituting for a fraction of what people consume from normal food supply systems (Kulak et al., 2013). There is a growing interest and potential for reducing emissions from food waste through food sharing where surplus is exchanged through social networks or online platforms among registered users such as private households, as well as by local retailers or farmers (Ganglbauer et al., 2014).

Recognizing the significance of food waste, several studies also highlight the benefits of managing unavoidable food waste properly as a potentially GHG-saving solution (Eriksson et al., 2015). In contrast to waste prevention that includes activities that avoid waste generation, the category of indirect improvement deals with improving waste management once waste has been generated. Those comprise improved use of food waste for animal feed, fertilizer, compost, or to recover energy from anaerobic digestion (Vandermeersch et al., 2014).

5 Conclusion

In this paper we have developed and presented a conceptual framework which illustrates prevalent strategies and sub-strategies for final consumers to mitigate GHG emissions. This new framework offers a comprehensive and holistic approach in addressing impacts from a consumption perspective, drawing on many studies from sustainable consumption and production. The distinction between various strategies may be crucial for future processes of prioritizing the options and putting in place supportive policy interventions. However, guidance on sensible strategies cannot be applied blindly, as the full environmental impacts of strategies depend on various site-specific factors and the interaction between impacts during the production phase and those during the use phase. In the course of our work, we often identified mitigation options that have been proposed by one study but were rejected by another study that claimed the opposite effect on GHG emissions. This is true for example in case of organic products (Tuomisto et al., 2012). Reducing one type of GHG emissions can lead to increases in another category. Similarly, reductions in GHG can cause trade-offs with other non-climate related environmental issues like water scarcity, land-use change or material resources intensity (Smith et al., 2013). It seems that even where absolute reductions could be possible it may lead to indirect or direct rebound effects and/or additional consumption (Hertwich, 2005). However, in the end, their effects depend not only on the technical mitigation potential but will be largely reliant on consumers' response to the adoption of those options and the political support that is provided.

What becomes clear is that there is no "one-size-fits-all" high-priority list of mitigation options to address the global mitigation challenge, but there are a number of actions that will need to be realised simultaneously and across all major consumption areas and product groups to achieve the emission reduction goals in developed countries. Each strategy on its own will face difficulties in realizing substantial reductions in GHG emissions, the various strategies in combination may deliver such reductions.

The proposed framework aims to challenge the current approaches to reduce emissions arising from consumption that mainly focus on efficiency improvements and energy conservation, in order to open up a more comprehensive debate about low carbon consumer strategies and influence the current academic thinking and policies on mitigation options to foster more sustainable solutions. The resulting framework considers not only the direct emissions but also encompasses the under-researched domain of embodied emissions in the discussion on sustainable consumption. Those embodied emissions may not only be tackled by more efficient upstream processes but also by applying the concepts of circular economy to consumers and by adopting the principles of the sharing economy. Although the thinking of circularity on the consumption side and the implementation of new collective models such as sharing require a fundamental re-thinking of current practices and systems in place, their wider application has the potential to deliver substantial environmental, social and economic benefits.

Considering the impacts of consumption throughout time, this paper suggests that a further step towards a more sustainable and less carbon intensive way of living and consuming is to tackle the entire supply chain, as opposed to focusing only on the production or the consumption stage. From the perspective of GHG emissions, there are significant life cycle environmental impacts that can directly be influenced by final consumers through altered behaviour. Within limits, consumers can exercise sustainable choice and use their power to call for more GHG substantive changes. However, consumers do not possess full control over the impacts arising during production. Their practices are for a large part shaped by infrastructures, social norms and habits that limit the ability to exercise free choice (Shove and Walker, 2010). Especially regarding emissions embodied in products, consumers only have limited information of the emissions that arise during production. Effective implementation depends on policies and collective efforts from a combination of producers, government as well as from consumers (Tukker et al., 2008). Hence, interventions should tackle both the individual practices of consumers, and the material and social context within which those practices are embedded (Geels et al., 2015). The realization of the strategies needs to be accompanied by improved infrastructure and technological solutions, supported by large-scale investment and local policies. Finally, identifying the main strategies and options will primarily provide the basis for deducing what kind of structural changes and political framework conditions and/or interventions are conducive to enabling citizens to adopt those actions.

Further research is required that consistently assesses the mitigation potential and different side-effects on other resources of the various consumer-oriented strategies, in order to obtain a more coherent picture of the net effects of each option. Such assessments could provide the evidence base to support the implementation and prioritization of the strategies, especially for those that have hardly been investigated thoroughly by industrial ecologists. This is also true for the social sciences, where more in-depth investigations are required to analyse factors that encourage or discourage the whole range of effective behaviours.

Finally, as discussed in the example of food consumption, it is clear that there are a variety of consumer actions that could be deployed in order to decarbonize the food sector. Potentially large reduction in GHG emissions is achieved by eliminating meat from the diet, followed by switching from carbon-intensive lamb and beef to less carbon-intensive pork and chicken. Cutting out all avoidable waste can also deliver considerable emissions savings. Not eating foods grown in hot-houses have a lower but still considerable potential for reduction in emissions.
However, current demand-side policies incentivising changes of food practices are rather incremental than transformative. Until today there are mostly soft political interventions like awareness campaigns, round tables, networks and information platforms in place that support the implementation of low low carbon food practices on the consumer side. A combination of more stringent measures like the abolishment of subsidies on food, stronger regulations and economic incentives combined with softer measures could be a key lever for behavioural changes in industrialised countries (Priefer et al., 2016).

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