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The Circular Household Model: A Framework for Implementing Circular Economy at the Micro Level

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Abstract

Rising global resource consumption and waste generation highlight the urgent need for change. This whitepaper focuses on the transition from a linear to a **circular economy (CE)** by taking a deeper look on the role of consumers within the CE. While existing research frequently focuses on the macro, meso or micro level itself, there is a lack of research taking a holistic approach when concentrating on CE. We take a deeper look into the interactions between the levels from the consumer perspective (micro level). The **Circular Household Model (CHM)**, developed within the Interreg project *Circ@Home*, addresses this gap by positioning households as active agents within the **Urban Circularity Triangle (Town–Home–Services)**, linking individual behavior with local infrastructures and service ecosystems. The CHM is operationalized through the **spider web model**, adapting R-strategies across food and non-food domains, allowing households to assess their circular practices and identify areas for improvement. As a conceptual tool, the CHM also enables researchers to analyze barriers and drivers of household-level circularity. Future research should empirically validate this model, refine its categories, and evaluate its scalability and transferability across socio-economic and cultural contexts. By integrating households into systemic CE strategies, the CHM contributes to evidence-based policymaking and sustainable consumption practices.

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1 Introduction

The current forecast for the material footprint – an indicator of the amount of resources extracted worldwide to meet consumption needs – shows an alarming trend: while global material consumption stood at 54 billion tons in 2000, it rose to 92 billion tons per year by 2017 (United Nations, 2025). Without effective counter measures, this number could rise to 190 billion tons by 2060 (United Nations, 2025). Over 2.2 billion tons of waste were generated in Europe alone in 2022. With around 193 million tons, a significant proportion of this waste comes from private households (European Parliament, 2024). The material footprint in tons of raw material equivalent per capita was 14 tons in the EU in 2023. (Europe's Material Footprint, 2024).

One of the main reasons for this environmentally harmful development is the prevailing linear economic system, in which products and raw materials are treated according to the "take-make-dispose" principle (Kirchherr et al., 2023). Resources only go through a single usage cycle, and many goods end up in the trash prematurely – often despite their potential for further use. The sequence of raw material extraction, production, use, and subsequent disposal is increasingly reaching ecological, economic (Kirchherr er al., 2023) and planetary limits (Stockholm Resilience Centre, n.d.). In addition, individual consumption significantly exceeds people's actual needs, while the resulting waste products are often disposed of inefficiently (Tari & Trudel, 2023). The United Nations identifies this development in its latest report, "Global Resources Outlook", as a key cause of the triple planetary crisis of climate change, biodiversity loss, and pollution (United Nations Environment Programme, 2024). For example, over 55% of global greenhouse gas emissions and over 90% of biodiversity-related land use and water stress are attributable to resource extraction and processing (United Nations Environment Programme, 2024). Environmental pollution, but also social inequalities and conflicts are on the rise (Urbinati et al., 2017; Voulvoulis, 2022; United Nations Environment Programme, 2024). These challenges are increasingly manifesting themselves as structural burdens and acute threats to societies worldwide: "Our current deeply unsustainable systems of consumption and production will culminate in catastrophic impacts on the Earth's systems and ecological processes that underpin human well-being and the diversity of life on our planet. This can, and must, change" (United Nations Environment Programme, 2024).

In order to counteract developments that threaten the future, it is necessary to recognize sustainable consumption as a necessity for society as a whole. This requires a fundamental systemic change that questions existing patterns of production and consumption and replaces them with resource-efficient, circular structures (United Nations Environment Programme, 2024).

One possible answer to the question of how a sustainable transformation can be achieved lies in the concept of the **circular economy (CE)**. This alternative economic model focuses on the ability of circularity of products, materials, and resources at the macro, meso, and micro levels (Grafström & Aasma, 2021). The aim is to minimize the use of primary raw materials, extend product life cycles, and significantly reduce waste volumes through reuse, repair, refurbishment, and recycling (Geissdoerfer et al., 2016). Such a systemic shift toward circular structures requires a move away from the linear "take-make-dispose" model toward closed material cycles (Geissdoerfer et al., 2016).

Various approaches already exist to implement the concept of the CE at different levels – for example, in housing (Ghafoor et al., 2023) and private consumption (Marchesi & Tweed, 2021), on the corporate side (e.g., Stifung Familienunternehmen, 2021 [eng. Family Businesses Foundation, 2021]), or in relation to individual product categories (e.g., Sonego et al., 2022). However, a meta-study by Kirchherr et al. (2017) shows that key dimensions of the CE have been neglected in many approaches and strategies to date. These include, in particular, systemic perspectives, social justice, and the active role of consumers and innovative business models (Kirchherr et al., 2017). In the long term, these shortcomings can significantly limit the coherence, acceptance, and impact of CE approaches (Kirchherr et al., 2017).

Current research findings underscore the importance of integrated cooperation at all levels. To address this gap, the **Circular Household Model (CHM)** has been proposed as a framework. It was developed as part of the Interreg project "Circ@Home – Resilience by circularity and sharing culture at households as a precondition for climate-neutral cities: Circ-in-Town = Circ@Home + Circular services." The international collaboration between five European countries (Germany, Finland, Estonia, Latvia, Sweden) aims to develop an innovative framework that establishes and strengthens circular consumption in households (Circ@Home – Interreg Baltic Sea Region, 2025). This whitepaper presents the first draft of the CHM, based on preliminary studies conducted within the project. As an early conceptual contribution, it is

subject to further development and refinement as the project progresses. Overall, the *Circ@Home* project strives to promote circularity at the individual and systemic levels with a focus on the environment and the infrastructural conditions that enable sustainable consumption behavior in the first place. Through the concept of the **Urban Circularity Triangle (Town–Home–Services)**, the project seeks to systematically link households, services, and municipalities in order to foster circularity at both the individual and structural levels (Stockholm Environment Institute Tallinn Centre et al., 2025).

As a core part of the project, the CHM aims to systematically investigate the role of private households in the triangle, in order to identify obstacles and challenges, and ultimately draw conclusions for services, towns and overarching policy. It should also provide households with the opportunity to reflect on their own behavior and make positive contributions to the overall goal of becoming more circular in their everyday life. The CHM itself focuses on promoting and structurally anchoring circular behavior especially at the level of private households.

The CHM concentrates on the individual level. On the one hand, it serves as an information system where households can gain information about circular practices and services. This gives the opportunity to rethink one's behavior and connects households and circular services. On the other hand, the model serves as a tool for researchers to gain better understanding how circular households are and where barriers and problems block the way to more circularity. This gives implications for services and households.

The purpose of this whitepaper is to answer the question of how private households can become an integral part of a CE without attributing sole responsibility to them. For this purpose, a theoretical and conceptual framework is first outlined, in which key terms, models, and approaches of the CE are introduced and defined. Building on this, we present the multidimensional "spider web model" as a submodel of the CHM. This forms the basis for practical implementation. The specific design of the R-strategies is then outlined with regard to individual categories on the food and non-food sectors, and local adjustments are explained. Accordingly, we display the further research plan for the theoretical and practical validation of the CHM across the Baltic Sea Region. The whitepaper concludes with outlining its goal of serving as a base for policymakers and administrators, enabling informed decision-making for the targeted promotion and implementation of sustainable circular strategies across different domains.

2 Framework

2.1 Concept of the circular household

The CE describes a new economy in contrast to the traditional, linear economy we are living in today. Linear economy extracts new resources, uses them to produce product and consumer goods and finally discards them as waste. In contrast, CE seeks to decouple resource consumption from value creation through three main strategies: “narrowing the loop by reducing overall resources use, slowing the loop by keeping products in use for longer periods, and closing the loop by recycling or repurposing resources rather than discarding them as waste” (Pacheco et al. 2025, p. 1). Ideally, the CE would involve materials from discarded products remaining of the same quality, so that no new natural materials are needed to produce the same product. This process could be repeated indefinitely without any loss of material (Potting et al., 2017).

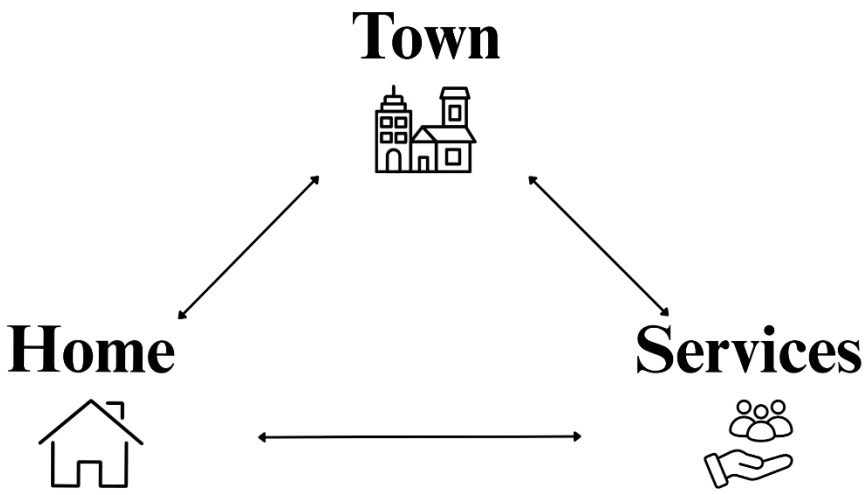
In the majority of discussions concerning the CE, the emphasis is on recycling (Kirchherr et al., 2023; Potting et al., 2017). However, while recycling is an important part of the CE process, it is essential to draw a distinction, e.g., between high-grade recycling, where materials remain high quality, and upcycling. It is important to note, that there are more subcategories. If we focus solely on recycling, the economy will continue to follow a linear model. To achieve a more ambitious CE, it is essential to adopt higher circularity strategies, such as rethinking or repair (Potting et al., 2017). It is imperative that society adopts a new mindset, recognizing the value in maintaining and preserving our resources rather than disposing of them hastily.

As previously mentioned, achieving a CE requires addressing several levels of the economy (Reike et al., (2017). At the systemic or structural level, the government is in a position to establish a legal framework that would support CE. This power is being exercised at a high level (e.g. by the European Union), with a significant impact on a wide range of individuals and organizations, including local governments, which in turn have a direct impact on their respective cities. The *Circ@Home* project will primarily focus on local governments, while also considering broader national and transnational governance issues. At the meso level, businesses and services have the opportunity to adapt circular business models and provide e.g., long-lasting and recyclable products (Ferasso et al., 2020). The micro level encompasses consumers. In order to achieve a CE, consumers play an essential role, alongside politics and producers. Due to behavior change, like circular consumption, consumers are able to support

the CE. Circular consumption is defined as “the set of consumers' activities, decisions, and behaviour following the principles of the circular economy (CE) is called a circular consumption system” (Gomes et al., 2022, p.1). The R-strategies outlined in chapter 2.2 demonstrate the spectrum of circular consumption behavior on a consumer level (Pacheco et al., 2025).

The different levels are also reflected in the Urban Circularity Triangle (Town-Home-Services), which gives the opportunity to show the interdependence of the levels (see figure 1). In this arrangement the structural level is described as town, meso level as services and micro level as home. Since each level has an impact on the other it is important to use a holistic approach in order to gain outputs help implementing the CE (Stockholm Environment Institute Tallinn Centre et al., 2025).

Figure 1: The Urban Circularity Triangle (Town-Home-Services)



Notes. Credit on behalf of the entire *Circ@Home* consortium.

The following sections will focus on the micro level: the home. A home, or more precise a household, consists all people and pets living together in an apartment or house. The focus is not only on households that are already interested in CE or sustainability. The aim is to reach a broader range of households in order to identify the barriers and problems associated with a CE lifestyle. As there is a small ‘bubble’ of individuals already interested in sustainability

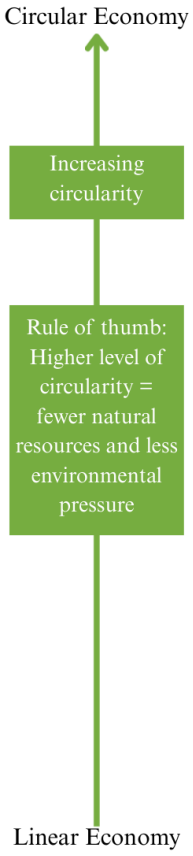
(Peyer et al., 2017; NIQ Sustainability Index, 2025), the greater challenge – and opportunity – lies in understanding the barriers faced by the majority who have not yet engaged with these issues (White et al., 2019). According to Rogers' Diffusion of Innovations Theory (2003), new practices are first adopted by a small group of innovators and early adopters, while the broader impact depends on reaching the much larger and late majority. This perspective highlights why it is crucial to move beyond the existing sustainability 'bubble' and better understand the barriers faced by households that have not yet engaged with CE lifestyles Addressing these barriers is essential not only for advancing research, but also for broadening societal acceptance of CE and strengthening our collective ability to confront the urgent risks of climate change.

2.2 R-Strategies from a household perspective

The field of CE is using the so-called R-strategies as an operationalization principle. The R-strategies consists of different 're-' words which means 'again', 'back' and 'anew' or 'afresh' in Latin. These words are used in the CE as a key operationalization, since they describe its essence. As Reike et al. (2017) show in their paper that there are up to 38 different 're-' words used in the context of CE. Depending on the research paper, between three and ten of these Rs are selected and used for operationalization. The *'reduce, reuse, recycle'* 3R typology is a very basic and often used concept linked to the waste management system (Reike et al., 2017). Some authors also put the Rs in a hierarchical sequence, from high influence to promote circular behavior to low influence.

The ten R-strategies drawn by Potting et. al. (2017) form the base for our CHM. They are classified from R0 (high impact on increasing the CE) to R9 (low impact on increasing the CE). Furthermore, the Rs are clustered in three superordinate groups: R0 – R2: *smarter product use and manufacture* with a high level of circularity; R3 – R7: *extend lifespan of products and its parts* with a medium level of circularity and R8 – R9: *useful application of materials* with a lower level of circularity (Potting et al., 2017). In 2024, the German government integrated this R-typology in their National Circular Economy Strategy [Nationale Kreislaufwirtschaftsstrategie] (BMUV, 2024).

Figure 2: Circularity strategies within the product chain (in order of priority)



Smarter product use and manufacture	R0 - Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1 - Rethink	Make product use more intensive (e.g. through sharing products, or by putting multi-functional products in the market)
	R2 - Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of products and its parts	R3 - Re-use	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4 - Repair	Repair and maintenance of defensive product so it can be used with its original function
	R5 - Refurbish	Restore an old product and bring it up to date
	R6 - Remanufacture	Use parts of discarded product in a new product with the same function
	R7 - Repurpose	Use discarded products or its parts in a new product with a different function
Useful application of materials	R8 - Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9 - Recover	Incineration of materials with energy recovery

Source: Potting et al. (2017, p. 15).

When focusing on households, the R-strategies suggested by Potting et al. (2017) should be modified. Since the *Circ@Home* project does not primarily focus on the product chain, as Potting et al. (2017) do, we selected the Rs which are more practical and feasible for everyday application. Consequently, the terms *remanufacture* and *repurpose* were excluded, while *rot* was introduced instead. The Zero Waste concept (Dada et al., 2024) was also taken into account alongside the concept of CE. The CE, as already described, is a system changing model which also addresses the economic and social besides the environmental dimension. The Zero Waste approach concentrating on the behavior of consumers and encourages to close the loop of product lifecycles (Dada et al., 2024). For the *Circ@Home* project, which attempts to present a holistic approach and operates at both the consumer and structural levels, it is therefore important to consider and combine both concepts.

The representation as an inverted triangle allows to visualize that the impact on circularity is higher in the upper Rs. As figure 3 shows, the circularity is increasing from *recover* (low impact) to *refuse* (high impact). Same as Potting et al. (2017), we clustered the R-strategies in three superordinate groups. *Use waste as a resource* covers the three Rs with a lower impact on circularity: *Recover*, *rot* and *recycle*. The group *extend product life* which includes *refurbish*, *repair* and *reuse* is listed in the middle and on the highest impact level the group *buy less and use smarter* which covers the Rs *reduce*, *rethink* and *refuse*. This approach facilitates engagement with groups who are less familiar with the specialized terminology of the CE in their everyday contexts.

Figure 3: Inverted pyramid of the R-strategies

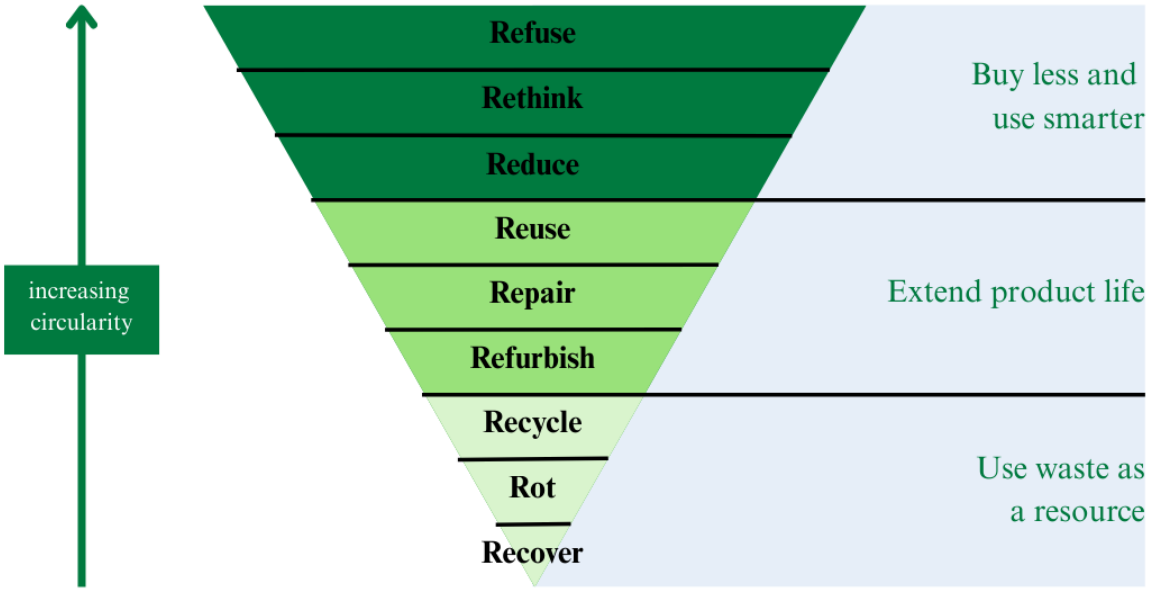
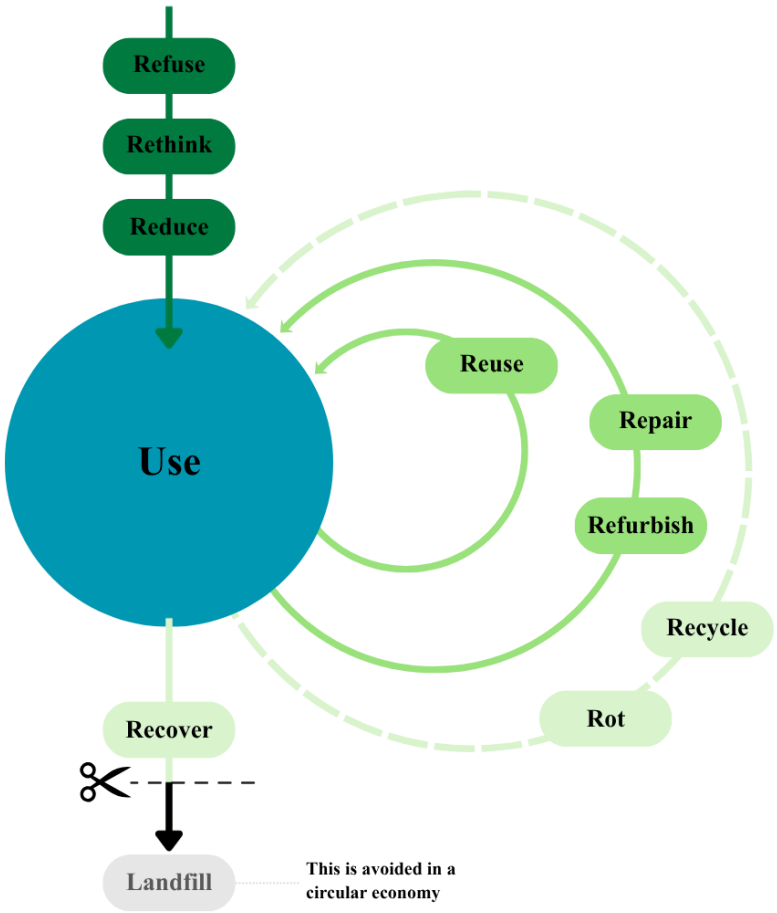


Figure 4 shows the R strategies in relation to use, based on the presentation by Potting et al. (2018). This presentation illustrates the material flow.

The strategies at the highest level, “Buy less and use smarter,” show that no new materials are needed. The focus is on behavioral changes, such as borrowing or sharing products. However, the figure does not take into account the possible rebound effect when products are used more often through sharing (Trabandt et al., 2025).

The *reuse* strategy is located in the innermost circle, as products are reused directly without additional material expenditure. In contrast to the highest R-strategies, however, the focus here is on individual ownership of materials rather than on a reduction in material consumption. Reuse describes the purchase of second-hand products that are in near-new condition. The product is like new, serves the same purpose, and does not need to be repaired or refurbished. In the context of online retail, returns or products with damaged packaging can also be included. Using packaging that can be used multiple times also falls under the category of reuse (Reike et al., 2017).

Figure 4: Circularity ladder



Source: Adapted from Potting et al. (2018).

Repair and *remanufacture* are located in the middle circle because, unlike reuse, new materials must be used to make products usable again. For example, a new screw or board must be used to repair a broken table.

The strategies *recycle* and *rot* are located on the widest circle. This classification results from the fact that these strategies require a high energy input in some cases and "only" so-called secondary materials are returned to use. Therefore, the line is also dotted, as the products are not necessarily returned to use in the same quality through recycling.

The lowest R-strategy, *recover*, is not included in a circle, as it often requires a very high amount of energy and has other negative external effects, such as pollution. The latter makes it clear in Figure 4 that landfilling has no place within the circular economy.

Furthermore, the *Circ@Home* project distinguishes between the food and non-food sector. This distinction enables a better understanding of how circularity can be achieved from a household perspective. One reason for this is, that the food and non-food sectors have different cycles, addressing different R-strategies. The food sector works with biological cycles and focuses on preventing food waste. In contrast, the non-food sector deals with technical cycles and aims to produce long-lasting products in a circular way. For example, recycling is a more important R-strategy in the non-food context, whereas rotting is more important in the food context. Another reason is the different political frameworks. The food sector is subjected to strict food and hygiene regulations, which often conflict with circular ideas. However, the non-food sector is not subject to the same stringent regulations; businesses are at liberty to adapt their products and services in terms of repair, reuse, redesign or upcycling. The stakeholders in the food and non-food sectors are also different. While supply chains in the food sector tend to be short and close to the end user, supply chains in the non-food sector are often long due to globalization.

2.3 Concepts for reducing resources

To better understand the nature of the different R-strategies, it is crucial to differentiate between *efficiency*, *sufficiency*, and *consistency* as each concept represents a distinct strategy for reducing resource use and environmental impact (Balderjahn, 2021; Brinken et al., 2022; Hoffmann & Akbar, 2024). Collectively, these strategies provide a more comprehensive understanding of how circularity can be advanced at the household level.

Efficiency

Efficiency aims to increase the output per input. This means that the efficiency or productivity of resource use should be increased. An example of this is LED lighting, which can produce the same brightness with less energy than incandescent bulbs. Efficiency often results from innovation and technical development. At first glance, it appears to represent a win-win situation, as no behavioral change is initially required, but it carries the risk of rebound or even backfire-effects (Reimers et al., 2021). The rebound effect occurs when consumers adjust their behavior so that potential savings from efficiency are not fully realized. For example, switching from a fuel-powered car to an electric car. Since the cost per kilometer is cheaper, this could lead to more intensive use, which would reduce the positive impact of the change. When the rebound effect is so strong that the potential savings are eliminated or leads to additional consumption it is called backfire-effect (Hoffmann & Akbar, 2024).

Sufficiency

Sufficiency means to balance consumption, no over- or underconsumption. It is derived from the Latin word ‘sufficere,’ which means ‘sufficient, enough’. In the western society this means to reduce consumption and only buy what is necessary. On the production side this means to produce long living products (Hoffman & Akbar, 2024). The consumer behavior literature discusses the construct of voluntary simplicity as an important sufficiency-based lifestyle (Alexander & Ussher, 2012; McGouran & Prothero, 2016).

Consistency

Consistency aims to imitate and preserve natural cycle. The main focus is to reuse resources and create a natural cycle. The goal is a macroeconomic shift toward production cycles that are based on natural cycles and convert waste into raw materials using environmentally friendly technologies, which are then used to manufacture new products. This does not necessarily require a change in lifestyle, but rather changes on the production side (Jacob, 2025).

It is evident that all three concepts must be given full consideration in CE and are integrated into both business practice and people's everyday lives, as the aforementioned examples demonstrate. It is therefore necessary to consider how the concepts relate to the R-strategies and how they can be integrated into the daily lives of households. Furthermore, consumers must be made aware of potential dangers, such as the rebound effect, in order to facilitate informed reflection on their behavior.

2.4 Circularity level

Using the inverted pyramid of R-strategies allows to measure the degree of circularity at the household level. The following chapters gives a better understanding of the three superordinate groups and how we define the Rs in the food and non-food sector.

2.4.1 Buy less and use smarter

The group *buy less and use smarter* combines the R-strategies *refuse, rethink* and *reduce*. These strategies focus on the concept of sufficiency and take preventive action. In the following sections, we will describe the different strategies more generally. Table 1 displays what each strategy means in the context of the food and non-food sector.

The highest R-strategy *refuse* means to buy or use less. This should be understood not only from the consumer's point of view, but also from the producer's point of view. Overall, this forms a critical position toward consumption and calls for a post-materialistic lifestyle (Reike et al., 2017) and is reflected in different types of anti-consumption (Chatzidakis & Lee, 2013; Garima & Joshi, 2025; Iyer & Muncy, 2009).

Potting et al. (2017) define the strategy *rethink* in a more product use-based way. This means to increase how often products are used due to sharing or multi-functional products. Morseletto (2020, p. 8) suggests a broader definition including "re-elaboration/reconceptualization of ideas, dynamics, processes, concepts, uses, and post uses of a product". The author claims rethinking as a main point for CE since it requires to rethink the current processes in order to reach a CE (Morseletto, 2020). This shows that rethinking can be applied at the systematic, meso or micro level. Sharing and collaborative consumption are prominent approaches that belong to the rethink strategy (Belk, 2010; Akbar & Hoffmann, 2023).

Reduce can be understood from a consumer or producer view or as a generic term. In general, the aim to prioritize avoiding the creation of waste over dealing with waste once it exists. On a consumer level *reduce* entails to use products with more care and for longer periods. Even extending the product life due to reparation can be understood as reduce, as this prevents the purchase of a new product. Furthermore, the sharing economy plays a central role in this strategy. For producers this means to adapt these ideas in the concept and design of their products (Reike et al., 2017). Potting et al. (2017) also mention the general reduction of resources in production. In addition, products should be multifunctional.

Table 1: Buy less and use smarter – Definition of the R-strategies in the food and non-food context

R-Strategy	Food	Non-Food
Refuse	Avoid unnecessary or wasteful food practices (e.g., impulse purchases, overpackaged foods), use packaging-free shops or your own containers to buy food.	Say no to unnecessary, low-quality, or short-lived household goods (e.g. avoid trend-based impulse purchases, low-quality "fast fashion" clothing, overpacked or single-use products).
Rethink	Change the way you think about food and food consumption (e.g. rethink your shopping routine by planning meals in advance, rethink how you interpret expiry dates to avoid throwing away food that is still safe to eat).	Shift your mindset to prioritize quality and longevity (e.g. rethink your wardrobe: invest in timeless, high-quality, versatile pieces instead of chasing trends, choose energy-efficient and durable appliances), consider borrowing instead of buying.
Reduce	Cut down excessive food consumption to prevent food waste before it happens (e.g. buy only what is needed, freeze extra food).	Cut back on the quantity and frequency of purchases to avoid unnecessary waste (reduce clothing purchases to what you truly need, reduce the amount of packaging).

2.4.2 Extended product life

Extend product life includes the R-strategies *reuse*, *repair* and *refurbish*. The focus is on preserving what already exists. The lifespan of products should be extended, thereby counteracting the concept of the throwaway society. As in section 2.3.1, the different strategies will first be described in more general terms. Table 2 then provides a more detailed description of their meaning for the food and non-food sectors.

The *reuse* strategy refers to returning products to the market after their initial use. Functioning products that are no longer needed should not be thrown away, but used by someone else. This exchange avoids the need to manufacture a new product (Reike et al., 2017). Second-hand shop and reusable packing belong the reuse-strategy (Noëth et al., 2024; Prisco et al., 2025).

Repair on the other hand implies the extension the lifetime of a product. First of all, it requires that products are designed in such ways that they can be repaired. The act of repairing/maintenance can be carried out by consumers themselves, either through peer-to-peer workshops or non-commercial repair cafés, or as a service provided by the product's manufacturer (Reike et al., 2017). In this context, it is important to consider the motivations and barriers. Because access to new products is often easier and cheaper than repairs, many

people buy new products instead of repairing them. The value/appreciation given to a product also plays a decisive role here (Lundberg et al., 2024).

The strategy *refurbish* can include repairs, but goes beyond that. This implies that the product is not just repaired, but that its components are upgraded to the latest technology (Reike et al., 2017). We include upcycling in the R-strategy of refurbishment. Even though refurbishment is more functional and upcycling is more creative. Upcycling gives a product a new purpose, which is why it is on a higher circularity scale than recycling (Stanescu, 2021). Both strategies aim to restore or increase the original value, though they use different tools to do so.

Table 2: Extend product life – Definition of the R-strategies in the food and non-food context

R-strategie	Food	Non-Food
Reuse	Give food and food-related items a second life through creative or practical reuse (e.g. reuse food leftovers in creative meals – cook with scraps, share food with neighbors, use and promote food banks and other local-level food sharing and donation initiatives/services, use reusable food containers, tableware and packaging).	Find new functions or second lives for items instead of throwing them away (e.g. donate clothes and functional items to reuse centers or second-hand shops, use reusable packaging).
Repair	In the case of food, repairing can be interpreted as restoring the value of damaged but edible food (e.g., removing bruised parts of fruit for juice production, making wilted lettuce fresh again).	Maintain and fix items to keep them in use for as long as possible (e.g. go to a repair café or community circular center to fix and repair items, learn to repair your clothing and other household items).
Refurbish	Similar to repairing, refurbishing aims to preserve the value of food products that might otherwise be discarded due to appearance or nearing expiration (e.g., make croutons from stale bread or jam from overripe fruit).	Restore a used product to good condition by cleaning, repairing, and updating it (e.g. refurbished laptop).

2.4.3 Use waste as a resource

Use waste as a resource recovers value at the end of the product life and includes the R-strategies *recycle, rot* and *recover*. These strategies come into play only when further use of the product is no longer possible. It is not feasible to address each strategy to the two sectors of food and non-food. Following the general description, Table 3 delineates the strategies that can be employed in each sector, along with the manner in which they can be implemented.

Recycling is probably the best-know strategy in the context of CE and the one which is already strongly integrated into the current economic system. Despite its frequency of use it has a lower impact on circularity. Recycling means processing post-consumption waste streams into "new", nearly pure materials using high-tech equipment (Reike et al., 2017). This process often uses a lot of energy and the products may not be as good as new materials, which is called downcycling (Helbig et. al, 2022).

Rot can be seen as biogenic recycling. It focuses on the food sector but could also play a role for natural materials in construction or packaging. The strategy refers to the natural breakdown of organic materials through composting or anaerobic digestion. Though it's one of the final steps in the CE, *rot* is essential for managing unavoidable organic waste in a sustainable, regenerative way (Sparnicht, 2025; Zero Waste Germany e.V., 2025).

The lowest impact for a CE has the strategy *recover*. This describes the collection and sorting of end-of-life products. Mostly it means extracting energy from materials that can no longer be reused or recycled. While not the most preferred option in the CE, *recover* ensures that even non-recyclable waste still contributes value before final disposal (Reike et al., 2017).

Table 3: Use waste as a resource – Definition of the R-strategies in the food and non-food context

R-strategie	**Food**	**Non-Food**
Rot	Turn organic waste into soil (e.g. participate in local/neighborhood food waste composting and use initiatives, urban agriculture and community gardens, use compost locally).	*- not applicable -*
Recycling	Turning food packaging back into secondary raw materials.	Turn discarded items back into secondary raw materials (e.g., participate in the source separation and separate collection system of household waste).
Recover	Use waste to recover energy, i.e. burning in waste-to-energy incineration plants, as the last option.	

3 Spider Web Model

3.1 Multi-dimensional approach to household circularity

To improve the understanding of circular consumption and to support households in implementing circular practices, a specific submodel was developed as part of the CHM: the spider web model. This model serves to explain and illustrate CE-oriented behavior and make it accessible to a broad target group. The spider web model (figure 5) is based on the 9 R-strategies (2.2) and general CE research, but in our case the spider web model is not seen as a linear hierarchy but as a multidimensional spectrum used to assess different product types (food and non-food) in terms of circular practices. The reason for this is the goal of the model's development: it should be applicable to all household types and individuals, regardless of social or economic conditions. Furthermore, the model does not differentiate according to the level of sustainability already achieved by households and does not seek to evaluate at any level, but rather to function as a support and incentive and to motivate. The model is guided by the multidimensional approach “no one is at zero and no one is at 100%, but has strengths and weaknesses.” This approach is intended to promote the motivation of the households and assess whether the model creates sufficient incentives to sustainably increase their degree of circularity. The long-term vision is to provide practical assistance to help households reach the next level of circularity. To ensure this and to provide an evidence-based structure, the *Circ@Home* project will test the model with households at a local level in eight different locations across the Baltic Sea region in the future.

3.2 Overview and visualization

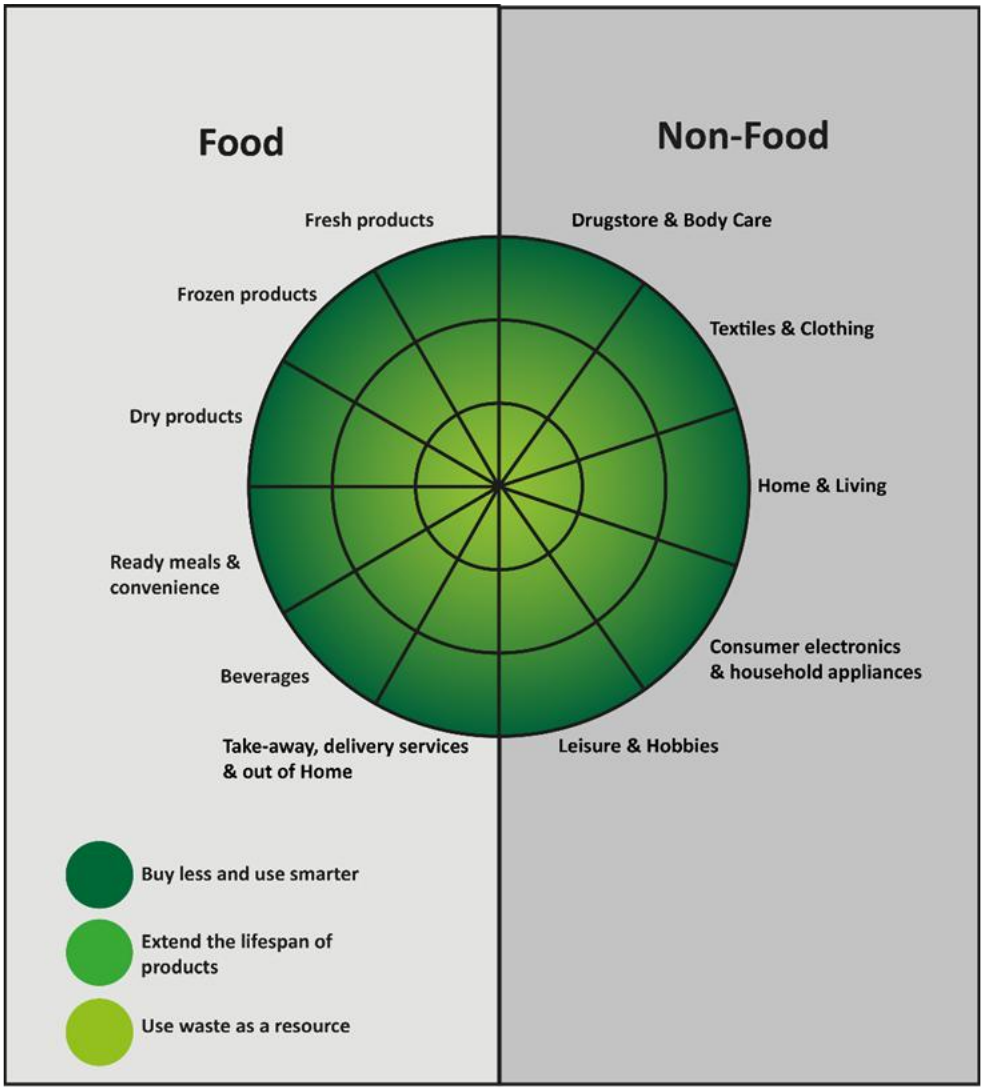
The spider web model is divided into the overarching categories "food" and "non-food," reflecting fundamentally different areas that need to be considered separately in the context of the CE. The specific categorization of the model can be adapted to different contexts, and this remains a subject of ongoing research. The preliminary approach presented here is based on initial investigations with consumers, experts, and generative AI. As a result of earlier research each of these areas comprises five to six carefully selected subcategories.

The food area includes the following six categories: fresh products; frozen products; dry products; ready meals and convenience; beverages; and takeaway, delivery services, and out-of-home. The non-food sector comprises five categories: drugstore and body care; textiles and

clothing; home and living; consumer electronics and household appliances; and leisure and hobbies.

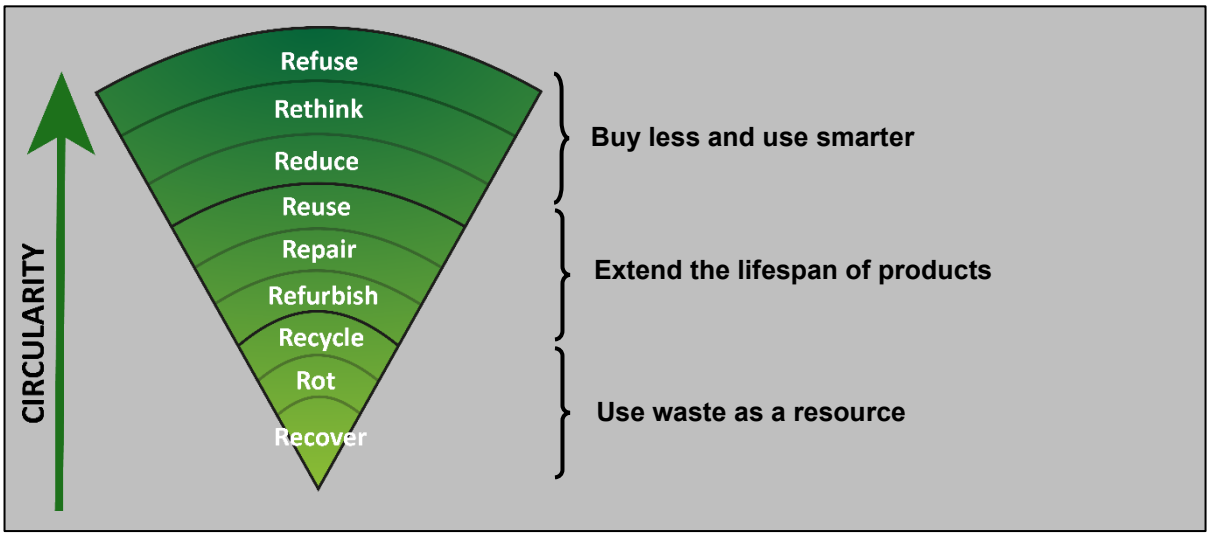
In addition to dividing products into categories, the spider web model differentiates between different levels of circularity, analogous to the R-strategies (section 2.3). Based on the R-strategies, these are subdivided into three dimensions: (1) “Buy less and use smarter,” (2) “Extend the lifespan of products,”and (3) “Use waste as a resource,” with the intensity of circularity increasing from the inside out. The color scheme – in particular the use of green tones and a consistent color gradient – was deliberately chosen to visually emphasize the central guiding principle that "no one is at zero and no one is at 100%, but everyone has strengths and weaknesses." By avoiding judgmental colors such as red, a neutral, continuous representation of circularity is ensured, thereby avoiding implicit evaluation.

Figure 5: The spider web model



The second level of the spider web model (see figure 6) represents the respective product categories. This opens up a new dimension that maps each of the nine R-strategies according to their degree of circularity. Consumers can locate themselves on the level that corresponds to their current status in terms of circular behavior, depending on the respective product category. Based on this, it is feasible to provide them with category-specific recommendations and supporting measures that are necessary to achieve a higher level of circularity. This gradually creates a personalized and differentiated overall picture across all levels of circularity, which can be evaluated independently at any time. Each household can mark their level of circularity in each category which will visualize how they increase or decrease.

Figure 6: Sublevels of the spider web model



3.3 Food Categories

As mentioned in the previous chapter, the categories were developed and differentiated in an iterative, participatory process involving both experts and consumers. Particular attention was paid to the practical relevance and applicability of the R-strategies in everyday life. In the original version, the spider web model consisted of 11 categories in the food dimension, which were reduced to five during the process. After intensive discussion, the category "Confectionery & Snacks" was not retained as a separate category, but will be divided into other categories depending on product characteristics in order to avoid overlaps and enable more targeted classification. The category "Special nutrition" was also removed due to a lack of distinction from the other categories. The category "Other" initially proposed was also

removed due to its lack of usefulness. The areas “Take-away & Delivery Services” and “Out of Home,” which were initially considered separately, were merged because both forms of food provision are characterized by external, non-independent preparation and thus present similar circular challenges and potential.

Another key topic in the category discussion was the handling of packaging. Due to its everyday presence and relevance in the context of circular consumption, it was decided not to list packaging as a separate category. Instead, it is always considered in conjunction with the respective product to ensure that R-strategies relating to packaging can be integrated in a meaningful way and assigned to the relevant application.

The following table provides an overview of the categories identified and related examples in the food sector:

Table 4: Overview of categories from the food sector

Food	Category	Examples
1	**Fresh products**	Fruits, vegetables, meat, fish, dairy products, eggs
2	**Frozen products**	Frozen vegetables, pizza, ice cream, ready meals
3	**Dry products**	Pasta, rice, flour, sugar, canned goods
4	**Beverages**	Water, juices, coffee, tea, beer, wine, spirits
5	**Ready meals & convenience**	Instant soups, microwave meals, breakfast cereals
6	**Takeaway, delivery services, & eating out**	Takeaway pizza, dining out in restaurants

3.4 Non-Food Categories

The categories in the non-food sector were also created based on an iterative reflection process that took into account both content overlaps and practical relevance in everyday life. Originally, the spider web model at this level contained 19 category suggestions, which were carefully discussed and ultimately revised. For example, individual categories such as "Baby & Toddler" and "Health & Medical Products" were deleted during the process because their contents could be meaningfully transferred to existing categories – in particular to "Drugstore & Body Care," which coherently integrates the corresponding product groups. The original "Home" category was expanded in terms of content and renamed "Home & Living" to include related product segments such as "Garden," "Seasonal Items," "Pet Supplies," and "Workshop & DIY

Supplies." The previously separate category "Travel & Outdoor" has also been subsumed under "Home & Living" due to numerous functional and contextual overlaps. The "Other" category has been eliminated in line with the approach taken in the food sector, as it did not provide any analytical clarity and could have led to confusion in the classification process. Similarly, it was decided not to list "Gift Items" as a separate category, as gifts can always be classified in other, more thematically appropriate categories depending on their context. A structural summary was carried out for the technical product areas: "IT, Computer Accessories, and Telecommunications" were merged with "Consumer Electronics and Household Appliances" to form a comprehensive category in order to represent technical consumer goods holistically and across all media. The category "Online Retailing/E-Tailing" was removed as it does not represent a separate product group. Instead, the corresponding articles are assigned to the categories that best match their content.

As in the food sector, packaging is always considered in relation to the respective product in order to ensure that R-strategies are applied in context and to reflect the high relevance of packaging in everyday life. Table 5 shows the final categories including category-specific examples.

Table 5: Overview of categories from the non-food sector

Non-Food	Category	Examples
1	**Drugstore & body care**	Shampoo, toothpaste, cosmetics, hygiene products
2	**Textiles, clothing**	Socks, underwear, towels, bed linens
3	**Home & living**	Furniture, decorations, candles, travel equipment
4	**Consumer electronics & household appliances**	Washing machine, refrigerator, dishwasher, stove, microwave, kettle, mixer, toaster, vacuum cleaner, iron, TV, radio, headphones, speakers, soundbars, smartphones, SIM cards
5	**Leisure & hobbies**	Books, magazines, toys, sports equipment

Local adjustments

As part of the Interreg project *Circ@Home*, a total of eight locations from four countries are working together to develop an innovative framework that enables and strengthens circular consumption. Each location has to deal with different circumstances depending on what it offers, preferences, and legal framework. It should therefore be noted that the specific

dimensions or categories of the CHM may vary depending on the country, location, or region. The aim is to provide a diverse and flexible model that can be adapted to the needs and requirements of all stakeholders and households.

4 Conclusion, Limitations and Future Research

The development of the CHM is a significant step towards systematically conceptualizing the role of private households in the CE. By focusing on the micro-level of consumption and linking it with services and municipal structures, the CHM expands the predominantly macro- and meso-oriented approaches of existing CE research. The spider web model is a valuable tool that can help to operationalize circularity in concrete categories and make it visible to households. This provides households with a diagnostic tool and a starting point for incremental change, allowing them to make informed decisions about their sustainability practices. In doing so, the model demonstrates that circularity is not only achieved uniformly, but rather develops along differentiated lines across food and non-food domains.

At the same time, the CHM faces several limitations. First, it remains a theoretical construct derived from literature analysis, expert discussions, and conceptual work. Its practical validity has not yet been empirically tested and still needs empirical specification regarding scales, indicators and measurement approaches. Second, the categories and R-strategies require further refinement to ensure that they are both analytically robust and applicable in daily household routines. Moreover, socio-economic diversity and infrastructural differences between households are not yet sufficiently integrated, which may limit the model's generalizability. Finally, there is a risk of overemphasizing individual responsibility if the systemic and political enablers of circularity are not addressed simultaneously.

Future research will address these limitations. As a next step, we will integrate the CHM into the existing Urban Circularity Triangle (Town-Home-Services) to enable the model to be systematically anchored in overarching value creation and circular processes. The model will then be tested in real-world context across the participating *Circ@Home* locations. Pilot studies will test the feasibility of different R-strategies in practice, explore household interactions with the spider web model, and provide feedback for revising categories and visualizations. Longitudinal research will be needed to assess whether engagement with the CHM leads to

measurable behavioral changes toward higher circularity over time. Beyond empirical validation, further research should also investigate scalability and transferability of the CHM across socio-economic and cultural contexts, and evaluate its integration into municipal CE strategies. In addition, interdisciplinary approaches could strengthen the CHM by integrating behavioral psychology, design thinking and digital innovation (e.g., apps or gamification) to enhance household engagement. The aim is to provide a robust, practical, and scientifically sound model that will then be subjected to a large-scale evaluation in several countries in the Baltic Sea region. The results of this cross-national study should not only demonstrate the practical feasibility of CE approaches in a domestic context, but also create a robust evidence base.

Finally, the CHM has the potential to evolve into a robust and scalable tool, that help municipal administrators and service providers to embed the CHM into broader CE strategies, ensuring that households are supported not in isolation, but as active parts of systemic transformation.

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