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The weakest link: how technical lifespan extension can be counter-effective for climate goals

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Abstract: Numerous studies have shown that service lifespan is lower than technical lifespan because users choose to discard products that are still functioning. Yet, the policy is mostly focused on the extension of technical lifespan, which means that extra resources are invested into ensuring more durable products that can land in waste bins equally fast. This work uses the example of kitchen durables to explore various lifetime extension scenarios and investigate the extent to which these interventions could in fact be counter-effective for climate goals set for 2050. We use material flow analysis to quantify the flows and stocks of appliances and furniture in Norwegian kitchens in 1990-2050. We apply the principle of the weakest link, in which the product is being replaced when it reaches the limit of its technical lifespan or social lifespan. Four lifetime extension scenarios explore various types of obsolescence (relative or absolute) and targeted products (on-the-market or in-use); each scenario assumes the policy implementation in 2025-2030, associated with an environmental penalty. We calculate life cycle impacts over the studied period using life cycle assessment and compare the cumulative emissions of extension scenarios against the baseline, in which no lifespan extension policy is assumed. The results show that design-for-durability policy could increase climate change impacts by up to 6%, which suggests that the current legislative efforts related to product lifetime extension could be counter-effective. The Repair scenario yields the highest net benefits thanks to its focus on in-use products, diverted from waste through repair. We suggest that user- and system-focused policy might yield faster effects and that measures could target particular durables.

Introduction

Product lifespan is determined by a variety of factors, some resulting from the product's intrinsic properties like the quality of materials, while others result from external factors like social norms, and availability of repair services. This duality corresponds to the concept of absolute and relative obsolescence (Cooper, 2004), product 'nature' and 'nurture' (Cox et al., 2013), or physical (technical) and social lifespan (Klepp et al., 2020), although many similar classifications related to product lifetime and reasons for obsolescence have been used (Packard, 1960; Sheth et al., 1991; Shi et al., 2022; van Nes & Cramer, 2005).

Product lifespan is often limited by non-technical aspects, as illustrated by products being discarded despite still being functional (Box, 1983; Cooper, 2004; DeBell & Dardis, 1979). Although some of these discarded products gain a second life, others end up in the garbage (Curran et al., 2007; Strandbakken & Lavik, 2018), thus not achieving their full lifetime potential dictated by their functional value. Even in the case of technical failure, behavioral and contextual factors can determine if the owner attempts product repair; any kind of repair was attempted in only 30-40% of failed kitchen appliances (Laitala et al., 2021).

Yet, the policy is focused on the extension of the technical durability of products. For example, the EU's legislative efforts are directed towards enhancing product durability and repairability, either through an extension of the Ecodesign Directive (COM/2020/98, 2020) or through a product labeling scheme (2020/2021(INI), 2020). These efforts, although needed, do not incentivize consumers to make the products last, or to repair them. Whenever the limiting factor to lifespan is not technical, any resources invested into more durable and repairable products are wasted resources, given that the products can land in waste bins equally fast. Such technical measures may therefore yield lower than expected resource savings due to behavioral factors, which is known as the rebound effect (Zink & Geyer, 2017); in some cases, the interventions may even lead to backfire – a higher resource use than in a no-intervention scenario.

This work uses the example of kitchen durables to explore various lifetime extension scenarios involving absolute and relative obsolescence and investigate the extent to which these interventions could in fact be counter-effective for climate goals set for 2050.

The durability of kitchen durables

In the last decades, the way we perceive kitchens has evolved, as described by Shove (2008, p. 22) “No longer a back region devoted to the preparation of food, kitchens are […] represented as places of sociability”. This transition is reflected in the increasingly popular open kitchen layout, where the living room is combined with the kitchen into one large sociable space. As a place of sociability, a kitchen is now more embedded into the social context, making the kitchen looks and the related social lifespan more important. Although no study has investigated whether the frequency of kitchen refurbishment has increased, qualitative research confirms that appearance and adjusting the kitchen to social needs are among the main motivations for kitchen refurbishment (Amilien et al., 2004; Hagejärd et al., 2020; Shove et al., 2008).

The changes in kitchens influence kitchen durables as well. Stoves, dishwashers, and fridges are often physically integrated into cupboards. Although such built-in appliances might sometimes be hidden behind a wooden board, this integrated design strengthens the interdependency between the appliances and kitchen furniture, both co-existing in the kitchen layout. Large kitchen appliances are therefore an integrated part of the furniture, and the furniture’s appearance is ‘extremely important’ (Gnanapragasam et al., 2018). These interdependencies increase the importance of the relative obsolescence of kitchen appliances, traditionally seen as ‘workhorse products’, which are generally valued for their functionality, are most likely to be discarded due to technical failure (Cox et al., 2013; Yamamoto & Murakami, 2021), and are more likely to get repaired (Jaeger-Erben et al., 2021; Laitala et al., 2021).

The relative obsolescence of kitchen durables should not be overlooked; for some appliances, the relative obsolescence is the reason for almost 50% of all discards (Strandbakken & Lavik, 2018). Both absolute and relative obsolescence can be the weakest point and cause discard (Figure 1). Reinforcing one link may mean that another link becomes the weakest one and becomes the limiting factor. In the same way, focusing entirely on absolute obsolescence disregards the importance of relative obsolescence, which would continue to weaken the system.

Figure 1. Product discard can be determined by absolute or relative obsolescence.

Methods

Major kitchen durables considered in this work are fridge, dishwasher, stove (oven and hobs), and kitchen cupboards. The flows and stocks of these durables are investigated in Norwegian households during the years 1990-2050 using dynamic material flow analysis (dMFA).

The model is stock-driven, where the stock was calculated by combining the number of dwellings and product ownership per dwelling. The number of dwellings is the population (Statistics Norway, 2023a, 2023b) divided by people per dwelling (Statistics Norway, 1891, 1904, 1913, 1952, 2021). The appliance ownership is taken from the literature (Bøeng et al., 2011; Halvorsen et al., 2005; Lien & Langseth, 2018; Sæbø, 1979; Statistics Norway, 2013), while the ownership of kitchen cupboards is assumed to be the equivalent of 14 standard-sized (60 x 60 x 80 cm) cabinets per dwelling, based on a random sample of 100 dwellings newly announced for sale on February 27, 2023, on a Norwegian website Finn.no. The lifetime was modeled as the Weibull distribution with the shape parameter 2.1 and the scale parameter calculated from average lifetimes: fridges 13.8 years, dishwashers 12.7 years, and stoves 14.1 years (Forti et al., 2018; Prakash et al., 2016; Wieser et al., 2015). The average lifetime of cupboards was assumed as 22 years, based on the number of kitchen cabinets sold in Norway (Braathen, 2015; Falck, 2021).

The climate change impacts per year were calculated using life cycle assessment (LCA), considering the production phase and electricity use during the use phase. The use phase was modeled like in Krych & Pettersen (2021). The impacts were calculated using GWP100 metrics, as given by the IPCC 2021 method (IPCC, 2021). Unit impact scores were sourced from ecoinvent v3.9.1 database (allocation cutoff) (Weidema et al., 2013), and were assumed constant throughout the simulation period.

The baseline scenario (*Baseline*) assumes the continuation of past trends, also regarding the product lifetime. Four alternative scenarios were developed, matching the reasons for obsolescence pictured in Figure 1. All four scenarios assume a policy intervention in the years 2025-2030 intended to extend product lifetime, which comes at a cost of an environmental penalty proportional to the total impacts in 2022 and uniformly spread across the five years. Each scenario assumes a 20% lifetime increase until 2030, but they differ in which products are targeted (on-the-market or in-use), and which type of obsolescence they address (absolute or relative). The share of absolute obsolescence in total obsolescence was assumed as 89% for dishwashers, 57% for stoves, 51% for fridges and 79% for cupboards, which are literature-informed assumptions (Laitala et al., 2021; Strandbakken & Lavik, 2018).

The *Reliability* scenario assumes design efforts focused on the technical reliability of products, which decreases the risk of absolute obsolescence by 20% in all products introduced to the market. The *Connection* scenario assumes design efforts focused on emotional durability and strengthening the product–user connection, which decreases the risk of relative obsolescence by 20% in all products introduced to the market. The *Repair* scenario assumes efforts centered around facilitating repair, e.g., increasing the availability of spare parts and convenience and pricing of repair services, which decreases the risk of absolute obsolescence by 20% in all in-use products. The *Culture* scenario assumes a change in social norms around the disposal of functioning items and frequency of kitchen renovations, which decreases the risk of relative obsolescence by 20% in all in-use products. The scenarios are summarized in Table 1. They are evaluated against each other by comparing their net environmental benefit – the relative difference of the scenario's cumulative climate change impacts compared to the baseline. Here, we consider the cumulative impacts in the years 2025-2050.

Table 1. Summary of the scenario framework.

Scenario	% obsolesc. reduction	Targeted obsolescence	Targeted products
Baseline	0%	-	-
Reliability	20%	Absolute	On-the-market
Connection	20%	Relative	On-the-market
Repair	20%	Absolute	In-use
Culture	20%	Relative	In-use

Results

The climate change impacts in the baseline scenario are dominated by production impacts, which make up 84-89% of the annual impacts in the years 2025-2050. Despite no use-phase impacts, cupboards are durables responsible for the largest share of impacts (Figure 2).

While the baseline climate change impacts develop smoothly after 2025, the alternative scenarios experience an initial impact increase caused by the environmental costs of the policy intervention (Figure 2). The impacts then level off at a lower-than-baseline level, which shows that each intervention succeeds in extending product use to some extent, which decreases production rates. Although both the Reliability and Repair scenarios display signs of lowered production in 2050, their impacts evolve differently. The Reliability scenario results in elevated levels of emissions in the entire period 2025-2030, with the curve almost parallel to the Baseline curve, proving little initial effect. On the other hand, in the Repair scenario the impacts initially soar in line with Reliability, but then gradually diverge. This gradual decrease in impacts corresponds to immediate effects offered by the Repair scenario, which targets all in-use products and prevents 20% of them from being discarded due to failure.

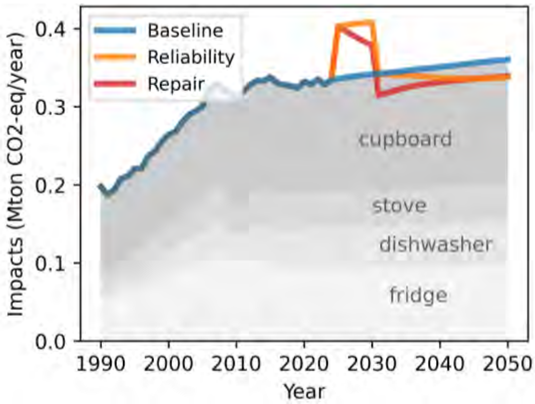

Figure 2. Annual climate change impacts – the totals for each scenario (line plot) and the Baseline composition by durable type (stacked area plot). Assumed a penalty of 100% of the impacts in 2022, spread over 5 years.

How environmentally beneficial a scenario is, is evaluated using the net impact with respect to the baseline (Figure 3). The net effects depend on the environmental penalty – the more resources we need to invest in executing an intervention, the more benefits are needed to offset it. However, some scenarios become beneficial (negative net impact) sooner than others. For example, assuming a penalty of 100% of the impacts in 2022 (just like shown in Figure 2), most scenarios show an impact increase: Reliability +1.5%, Connection +3.1%, Repair -1.3%, Culture +2.1%. The Connection scenario can therefore be the most detrimental to the environment, while the Repair scenario is an environmental benefit in most cases. Interventions involving absolute obsolescence are more effective (Repair, Reliability) than those involving relative obsolescence (Culture, Connection), given that the majority of kitchen durables are still discarded because of failure. Interventions targeting in-use products (Repair, Culture) yield faster effects than those targeting on-the-market goods (Reliability, Connection), which gives preference to them in a shorter time horizon.

Discussions

When designing lifetime extension strategies, it is important to address the weakest link within the list of factors that determine obsolescence. For kitchen durables, the weakest link is typically the product's technical reliability, but also the degree to which repair services are used. The modeling work shows that lifetime extension measures focused on these aspects yield higher benefits than those of measures focused on relative obsolescence. However, the benefits might not be as high as expected, because by addressing absolute obsolescence, the Reliability and Repair scenarios leave the relative obsolescence aside. This creates a rebound effect, where the intervention planned for extending product lifetime by 20% can only address its technical component, while the social lifespan remains unchanged and thus decreases the potential benefits down to barely a few percent.

The results also show that design-based solutions to longer life bring environmental benefits only in a medium-to-long timeframe. Although design for durability has gained a lot of interest in research and policy, the supporters of such solutions typically overlook what it takes to replace all products with more durable equivalents. The model developed in this work considers such systems dynamics, demonstrating that the longer the products last, the longer it takes to replace their entire stock. The potential environmental benefits may come too late considering many countries' climate goals set for 2050. In fact, this work has shown that policy extending technical lifespan through design (scenario Reliability) could be counter-effective for 2050 climate goals, increasing the net climate change impacts by up to 6%, assuming an environmental penalty size of 200% of the impacts in 2022. Although the penalty size considered in this work was chosen arbitrarily, any kind of intervention certainly involves some environmental costs. Lifetime extension strategies are generally not for free so carefully planning the details of their implementation can prevent a backfire effect.

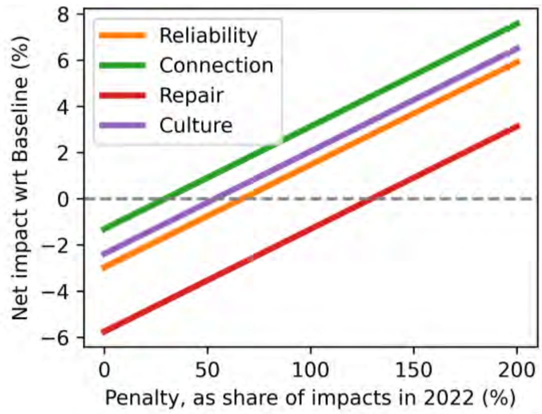

Figure 3. Net environmental impacts with respect to the Baseline as a function of the penalty size.

To overcome the time delay of design-focused measures, we suggest that a change to more user- and system-focused legislation might be beneficial. For example, faster environmental benefits could be achieved by increasing the repair rates by extending product warranties, subsidizing repair services, supporting the development of innovative repair businesses, demanding the availability of spare parts at affordable prices, and increasing the convenience of repair. Ideal policy proposals could target products with a high share of absolute obsolescence, e.g., dishwashers, which also fail more frequently than other appliances (Laitala et al., 2021). Products with high relative environmental impacts could also be prioritized, e.g., lifetime extension of kitchen cupboards could bring more benefits than any one kitchen appliance.

Finally, this work assumed that relative and absolute obsolescence are independent. This might not be the case in reality, as absolute and relative obsolescence can influence each other. There exists qualitative evidence that absolute and relative obsolescence of kitchen and kitchen durables can coexist, i.e., Amilien et al. (2004) noted that their respondents often started motivating their recent kitchen renovation by describing timeworn kitchen items, to finish off by criticizing the kitchen looks. Sometimes the absolute obsolescence of one item can cause the relative obsolescence of another, acting as a trigger, like in the case of a family that "needed to replace the floor joists, [so] they took the opportunity to completely transform the kitchen at the same time" (Hagejärd et al., 2020). Following this, we could speculate that an increase in the technical lifespan of one kitchen durable could in turn extend the social lifespan of interconnected goods, which could otherwise get discarded too. However, these interdependencies were not included in the current model due to a lack of quantitative data. Future work could involve collecting more evidence on the interaction of absolute and relative obsolescence.

Conclusions

This work explored four different scenarios implementing lifetime extension of kitchen durables. Although these goods are known for the importance of their technical lifespan, we show how the focus on absolute obsolescence and leaving out the relative obsolescence might decrease the environmental benefits of these scenarios, which could be seen as a type of rebound effect. We also show that design-focused interventions take longer to bring effect, which might make them counter-effective for climate goals set for 2050. We suggest that user- and system-focused policy might yield faster effects, just like a focus on particular durables.

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