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A Circular Economy Life Cycle Assessment (CE-LCA) model for building components

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ABSTRACT

The transition towards a Circular Economy (CE) in the built environment is vital to reduce resource consumption, emissions and waste generation. To support the development of circular building components, assessment metrics are needed. Previous work identified Life Cycle Assessment (LCA) as an important method to analyse the environmental performance in a CE context. However, questions arise about how to model and calculate circular buildings components. We develop an LCA model for circular building components in four steps. First, we elaborate on the CE principles and LCA standards to identify requirements and gaps. Second, we adapt LCA standards and propose the 'Circular Economy Life Cycle Assessment' (CE-LCA) model. Third, we test the model by assessing an exemplary building component: the Circular Kitchen (CIK). Finally, we evaluate the CE-LCA model with 44 experts. In the CE-LCA model, building components are considered as a composite of parts and materials with different and multiple use cycles; the system boundary is extended to include these cycles, dividing the impacts using a circular allocation approach. The case of the CIK shows that the CE-LCA model supports an ex-ante assessment of circular building components in theoretical context; it makes an important step to support the transition to a circular built environment.

1. Introduction

The building sector is said to consume 40% of global resources, and to generate 33% of all emissions and 40% of waste globally (Ness and Xing, 2017). The concept of the Circular Economy (CE) – originating from several schools of thought and popularised by the Ellen MacArthur Foundation (2013) – proposes an alternative to the linear economy of 'take-make-use and dispose'. The CE aims to enable economic growth without an ever-growing pressure on the environment (Pomponi and Moncaster, 2017). We understand CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing and narrowing material and energy loops." (Geissdoerfer et al., 2017 p. 759) Narrowing loops is reducing resource use (i.e., increasing efficiency); slowing loops means prolonging the use of (building) components, parts and materials by extending lifespans and introducing multiple cycles; closing loops is to (re)cycle materials from End-of-Life (EoL) back to production (Bocken et al., 2016). The cycles in the CE can be divided into biological and technical material cycles (Ellen MacArthur Foundation, 2013). Value Retention Processes (VRPs) – also called R-imperatives – are key in realising the cycles in a CE (Potting et al., 2017; Reike et al., 2018; Wouterszoon Jansen et al., 2020). Examples of VRPs are reduce, repair, re-use, and recycle; we refer to the framework of Wouterszoon Jansen et al. (2020).

As the building sector has the highest share in resource consumption, emissions and waste generation of all industries (Ness and Xing, 2017), the transition towards a CE in the built environment is vital to create a more sustainable society. The built environment can be made more circular by integrating CE principles in building components. These components can be placed in new buildings and in existing buildings during maintenance and renovation to gradually make the existing stock more circular. To integrate CE principles in building components, integral changes in their designs, supply chains, and business models are needed (Bocken et al., 2016; Ellen MacArthur Foundation, 2013; Hart et al., 2019; van Stijn et al., 2020; van Stijn and Gruis, 2020; Wouterszoon Jansen et al., 2020). Yet, there are many possible design alternatives for (more) circular building components (van Stijn and Gruis,

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2020). A roof which is constructed with non-virgin materials, or modular, or bio-based and biodegradable could be considered more circular in its own respect. To transition to the 'most' circular built environment, we need to assess which designs result in the most environmentally-circular building components; so, an assessment method is needed.

In previous research, two methods are often identified to support assessment of environmental performance in the CE: in a Material Flow Analysis (MFA), mass balances are calculated over time to identify the state and changes of material flows within a defined system (Corona et al., 2019). MFA can be used to analyse quality of resource flows (e.g., virgin, renewable, recycled) and the resource consumption of building components in a CE (Elia et al., 2017; Pomponi and Moncaster, 2017). Life Cycle Assessment (LCA) is the best-defined method to analyse environmental impacts, and can be applied in a CE context (Pomponi and Moncaster, 2017; Scheepens et al., 2016). The focus in this paper is on applying LCA to assess environmental impacts in circular building components.

In LCA, the environmental impacts of a building (component) are assessed along (parts of) its life cycle. However, conventional LCA studies focus on analysing the impact of a building for a single service life (cycle) (Eberhardt et al., 2020; Hauschild et al., 2018; Suhariyanto et al., 2017). Whereas in a CE, within the building (component) life-cycle, parts and materials – potentially – have different and multiple (use) cycles (Eberhardt et al., 2020; van Stijn et al., 2020; van Stijn and Gruis, 2020; Wouterszoon Jansen et al., 2020). Methodological questions arise: how to apply LCA in circular building components with multiple cycles?

Approaches to multiple cycles in LCA are discussed in standards (EN 15804, 2012; EN 15978, 2011; ISO 14040, 2006; ISO 14044, 2006), and have been compared for short-lived, products (e.g., Allacker et al., 2017; van der Harst et al., 2016), for re-use of building components (see De Wolf et al. (2020)) and in a circular built environment context (see Eberhardt et al. (2020)). Allacker et al. (2017) compared 11 allocation approaches. Only the 'Linearly Degressive' (LD) approach included all cycles of the product system within the product assessment. Ultimately, Allacker et al. (2017) preferred to (only) include the previous and subsequent cycle of the product within the assessment as they found predicting all cycles challenging. On the other hand, Eberhardt et al. (2020) suggested the LD approach incentivizes narrowing, slowing and closing cycles both now (i.e., downstream) and in the future (i.e., upstream). They built upon the LD approach, presenting the CE LD approach. De Wolf et al. (2020) posed that the allocation approaches they compared – including LD – did not assess re-use of building components accurately, concluding that further development is needed.

These studies focused on allocation, concluding with recommendations and/or (optimized) allocation formulas. Studies addressing CE adoption in building LCA remain sparse (Hossain and Ng, 2018). Comprehensive and practical guidance to apply LCA in circular building components remains lacking. Doing such an LCA, we touch upon multiple methodological questions: how to set the system boundary and model the system; how to apply an allocation approach which shares impacts between all cycles; how to address system uncertainties? In turn, it influences how to define the object of the assessment, period of assessment, functional unit, stages of assessment, modelling of the Life Cycle Inventory (LCI), calculations of environmental impacts (LCIA), and sensitivity analysis. Consequently, adaptations to LCA standards for building products and buildings – such as EN 15978 (2011) and EN 15804 (2012) – are needed.

We built upon the aforementioned allocation studies; we depart from the application perspective by exploring how these abovementioned methodological questions can be addressed in multi-cycle LCAs – and testing the (dis)advantages. By adapting existing building LCA standards, we aim to propose a model to apply LCA in the development of circular building components.

2. Method

An iterative, stepwise approach was used to develop the model (see Fig. 1). In step 1, we elaborated on key principles of CE in building components and analysed how existing LCA standards deal with these; we identified potential gaps in theory and current standards, and defined requirements for LCA of circular building components. In step 2, we built on the existing LCA standards, proposing the CE-LCA model for building components. In step 3, we tested the CE-LCA model by applying it in the assessment of an exemplary circular component: the Circular Kitchen (CIK). In step 4, we evaluated the model with experts. Iterations of refinement, test and evaluation were continued until the model fulfilled the requirements and the evaluation step yielded no new remarks by the experts. This paper is structured following these steps – presenting the final iteration of the CE-LCA model.

3. Key principles, gaps and requirements for LCA of circular building components

3.1. Integrate multiple levels in LCA: building component as a composite of parts and materials

To cycle building components at their highest utility and value, we should consider the building components as a composite of parts and materials, each with their own – optimised – lifespan. Duffy coined the concept of 'shearing layers', which was later elaborated on by Brand (1994): a building consists of 'layers' with their own lifespan which could be changed independently. Similarly, building components could be regarded as a composite of parts and materials with different lifespans. Per building component more levels (e.g., sub-components, resources) or fewer could be identified.

To increase the overall lifespan of building components, parts and materials might be exchanged at a different rate (Bocken et al., 2016; Wouterszoon Jansen et al., 2020). Alternatively, parts or materials might have longer lifespans than the building component. Consider a façade with a 30-year lifespan and brick finishing with 75-year lifespan. Commonly bricks are laid using mortar making them hard to separate and re-use after 30 years. If during design the 'layers' were differentiated based on lifespan, alternative finishing materials and – equally important – joining-techniques could have been considered to prevent

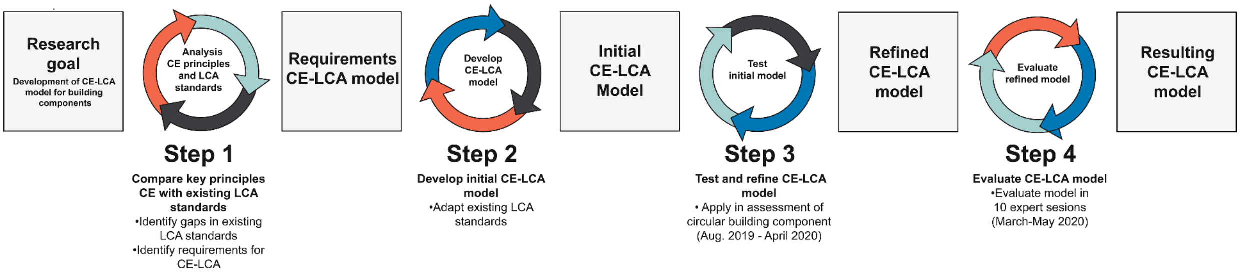


Fig. 1. Iterative approach for developing, testing and evaluating the CE-LCA model based on Peffers et al. (2007).

premature disposal.

Current European LCA standards focus on building (EN 15978, 2011) and building product (EN 15804, 2012) assessment. An intermediate link – on building component level – is missing (Lützkendorf, 2019). In the EN 15978 (2011), the building is considered as a composite of components, parts and materials with different lifespans. Yet, different levels of the building system are commonly not integrated into a single LCA. How multiple levels are 'connected' can influence the lifespans and cycles of each element in the system; optimising these is a key principle to keep elements cycling at their highest utility and value. Therefore, a multi-level LCA is required in CE-context. For a building component LCA, this means including underlying levels such as parts and materials; as the building component is installed in a building, the cohesion with the building level should be considered.

3.2. *Consider the interplay of different lifespans*

Understanding the interplay of different types of lifespan is vital to slow and close loops optimally. For example, Geraedts et al.(2009, p. 298) distinguish technical, functional and economic lifespan. The technical lifespan is defined as "the maximum period during which it can physically [perform]" (Cooper (1994, p. 5). The economic lifespan is the period in which the benefits outweigh the costs (Geraedts et al., 2009). The functional lifespan can be influenced by regulations and changing user needs, including the function or appearance of the building component (Geraedts et al., 2009; Méquignon and Ait Haddou, 2014). By analysing the interplay of different lifespans – in the entire building component system – the *leading lifespan* can be identified. This is 'the weakest' link determining the obsolescence – and replacement rate – of (parts of) the system.

Assumptions on lifespan in LCAs are complex; how they are made varies. When applying LCA, Reference Service Lifespans (RSL) of building types are provided in national standards (e.g., Stichting Bouwkwaliteit (2019, p. 37)). Building product and material RSL may be found in reference lists which could be based on argued assumptions by the producer (Stichting Bouwkwaliteit, 2019, p. 13) or calculated by balancing the technical, functional, aesthetic and economic lifespan (e.g., Aagaard et al. (2013)). For newly-designed circular components, an estimated Service Life (SL) needs to be determined. ISO 15686, 2011 provides the standard for SL planning for buildings – including for 'innovative' components. It includes the 'factor method' in which the 'Estimated SL' of the component is calculated by multiplying its RSL by a number of factors that affect the technical lifespan (e.g., 'material quality' or 'work execution level'). However, no functional or economic lifespan factors are included. Previous work concluded that buildings or components are replaced more frequently than assumed (Barras and Clark, 1996; Seo and Hwang, 2001; Slaughter, 2001) indicating that the functional or economic lifespan was shorter than expected. Junnila & Horvath (2003) argue that the influence of obsolescence is insufficiently considered in LCA. In CE-LCA, the interplay of the technical, functional and economic lifespan should be considered for all elements of the building component system.

3.3. *Integrate VRPs in LCA system boundary*

To slow and close cycles optimally, each element of the building component system might have multiple and different use cycles, requiring different VRPs. These cycles can be 'open-' or 'closed loops': In recycling theory, closed loops refer to recycling for the same quality or use (Huysveld et al., 2019). However, in circular supply chains, closed cycles may refer to VRPs realised by the industry(partners) involved in the original production (French and LaForge, 2006; Genovese et al., 2017). Additionally, VRPs can take place 'inside' the assessed building component, or 'outside'. For example, windows can be refurbished and re-installed in the same façade, or they can be re-installed elsewhere.

Guidelines for dealing with multiple cycles (also named 'multifunctionality' or 'secondary functions') can be found in LCA standards (EN 15804, 2012; EN 15978, 2011; ISO 14040, 2006; ISO 14044, 2006). The ISO 14044 (2006) includes a hierarchical procedure explained well by Bjørn et al. (2018, p. 90): dividing impacts between cycles – i.e., allocation – should be avoided by (1) dividing the processes between the cycles and 'cutting off' the processes of secondary cycles. If this is not possible, then (2) 'system expansion' should be applied: multiple cycles are included in the system boundary (e.g., through displacement or avoidance of impacts). If system expansion is not possible, (3) allocation should be used. The European building LCA standards – EN 15804 (2012) and EN 15978 (2011) – handle multifunctionality by combining approaches. Impacts from production, use and waste disposal (module A-C) are calculated using the 'cut-off' allocation approach; the system boundary is extended to include re-use, recycling and recovery potential of building products and materials in one subsequent cycle. The net benefits and burdens are reported separately in the informational module D.

In a CE-LCA, the abovementioned approach is problematic for two reasons. First, it is difficult to standardize crediting of re-use, recycling or recovery benefits (de Valk and Quik, 2017; Delem and Wastiels, 2019; Eberhardt et al., 2020; Wastiels et al., 2013). Second, cycles prior to the SL of the assessed building component or after one subsequent cycle remain invisible: they are not included in the scope of the assessment. In CE-LCA, the VRPs for all cycles in the building component system should be included in the system boundary of the assessment; these include VRPs inside and outside the assessed building component.

4. Towards a circular economy life cycle assessment model

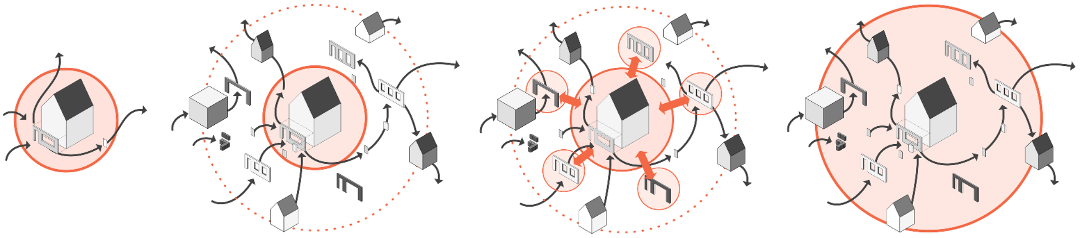
We built upon EN 15804 (2012) and EN 15978 (2011) to develop a Circular Economy Life Cycle Assessment (CE-LCA) model for building components which fulfils the requirements identified in section 3. We explore how the methodological questions mentioned in the introduction can be addressed. We present the CE-LCA model following the LCA phases (adjusted from ISO 14040 (2006)): (1) goal and scope definition, (2) CE Life Cycle Inventory (CE-LCI), (3) CE Life Cycle Impact Assessment (CE-LCIA), and (4) interpretation of results.

4.1. *Goal and scope definition*

In phase 1, the goal and scope of the CE-LCA is defined, addressing the object of assessment, functional unit, and system boundary.

4.1.1. *Object of assessment in CE-LCA*

In current standards, the object of assessment is 'the building (component) during its SL, including re-use and recycling potential'; previous cycles and cycles after one future cycle are not considered. If we consider all cycles, the object becomes 'the entire building component system including all use cycles'. This might be useful to assess the impacts of entire circular systems. Yet, it hinders comparability of individual building components as impacts of multiple uses are integrated into one assessment. In CE-LCA the purpose is to assess a building component within a circular system. Herein we distinguish two possible objects of assessments. Consider, a kitchen with fronts which can be re-used once. A possible object of assessment could be to determine the environmental impacts of an *average* kitchen within the circular system. We then assume that half of the fronts are made with virgin material and half with second-hand material. Such analysis is relevant to determine Environmental Product Declarations (EPD) of standardized designs, to assess a Product-Service System (PSS) or for LCAs in early-stage design. However, in some cases, we need to determine the impact of a *specific* kitchen within the circular system. For example, if we apply a kitchen with second-hand fronts in a building, we should only declare impacts of second-hand fronts. Such analysis is relevant in the context of LCAs for building projects. See Fig. 2 for an overview.



Object of assessment:	**Building component for a single service life, including re-use or recycle potential**	***Specific* building component in a circular system**	***Average* building component in a circular system**	**A circular building component system**
Usable for assessing:	**Linear or non multi-cycling building components**	**Circular building components in a building project**	**Circular building component EPDs, PSS, mass-produced building components, early-stage designs**	**Circular systems**

Fig. 2. Overview four 'objects of assessment' in CE-LCAs for building components.

4.1.2. Functional unit in CE-LCA

The functional unit (FU) of a CE-LCA for building components follows the template: "the use of an *average/specific what, quality,* in a circular system over a period of *x years*". The template adapts the EN standards and follows Suhariyanto et al. (2017) who concluded that the FU of a multi-cycle LCA should be based on function or activity.

4.1.3. System boundary in CE-LCA

In EN 15978 (2011), the life cycle of a building (component) – and system boundary of the LCA – is described in modules A, B, C, and D. We have adapted this framework, applying elements of the butterfly model of the Ellen MacArthur Foundation (2013) and the VRP framework of Wouterszoon Jansen et al. (2020). We extended the system boundary to include all use cycles on all levels of the building component lifecycle. We identify four modules and 45 life cycle stages in a CE-LCA (see Figure 3). Module CE-A 'Production, construction and pre-use' commences with the extraction and supply of the virgin materials and ends with the installation of the assessed building component in the building. If non-virgin material is applied in the building component, module CE-A also includes all the previous use cycles of this material. Module CE-B is the use of the building component. Module CE-C reports all following VRPs of the building component, parts and materials. Module CE-D reports on the final disposal of the material back into the bio and techno sphere.

4.1.4. Reference study period

In the LCA standards, the Reference Study Period (RSP) is aligned with the SL of the building (e.g., 60, 75, 100 years). At $t = 0$ the building (component) is constructed. At the end of the RSP, the building (component) is (assumed to be) demolished and materials are re-used, recycled or disposed. This approach increases comparability. In CE-LCA, the RSP – and what happens when – is more precarious to determine. We assume that at $t = 0$ the building component is constructed and taken into use. Yet, materials and parts could have been produced and cycled prior to this moment ($t<0$); and they might cycle long after the assumed SL of the building component has ended. To be able to assess if 'loops are slowed', the (functional, economic and technical) lifespans for the building component, parts and materials need to be reported exact. Therefore, the RSP should be determined by the longest, leading lifespan within the assessed building component. To ensure comparability, the impact may be calculated back to an impact/time unit (e.g., impact per x year(s)).

4.2. Circular economy life cycle inventory

In phase 2 of the CE-LCA, the CE-LCI is made in accordance with the system boundary described in section 4.1.3. See a model flowchart in Fig. 3. Building components need to be inventoried as a composite of (e.g.,) parts and materials. Materials with different use cycles within their lifecycle and different lifespans should be distinguished; all VRPs and use cycles are inventoried. Processes occurring 'inside' the assessed building component are included in the 'foreground system'; processes occurring 'outside' are part of the 'extended foreground system'. Note that in the CE-LCIA (Section 4.3), impacts are allocated at the material level. So, processes taking place on part or building component levels (i.e., lifecycle stages CE-A.3.2 to CE-C.3.6) should be divided (e.g., based on mass) over and modelled on the associated material level. For example, a kitchen front (consisting of a coated board) is re-used. Then a fraction of the processes of the re-use cycle is included in the lifecycle of the board material and the remaining fraction in the lifecycle of the coating material.

4.3. Circular economy life cycle impact assessment

In phase 3, 'the CE-LCIA', the environmental impacts are calculated from the CE-LCI.

4.3.1. Allocation approach for CE-LCIA

When calculating the impacts, dividing burdens between cycles is a leading consideration. As discussed in section 3.3, there are many different allocation approaches and the approach applied in EN 15978 (2011) and EN 15804 (2012) is less suitable for CE-LCA as all cycles should be included.

Alternative approaches can be found in previous works on 'multi-cycle LCA' (mLCA) and research on allocation. In the mLCA method by CE Delft et al. (2016), multiple subsequent cycles are included through the avoidance of future primary production in the form of an 'up-front credit'. Already introduced in the introduction, the LD (Allacker et al., 2017) or CE LD (Eberhardt et al., 2020) approach allocates impacts between cycles: the largest share of initial production and disposal impacts is allocated to the cycle where they occur, namely the first and last, respectively. The share of impacts allocated to following or previous cycles reduces linearly. The impacts of VRPs are divided evenly between cycles.

Different approaches could have merit in different instances. For

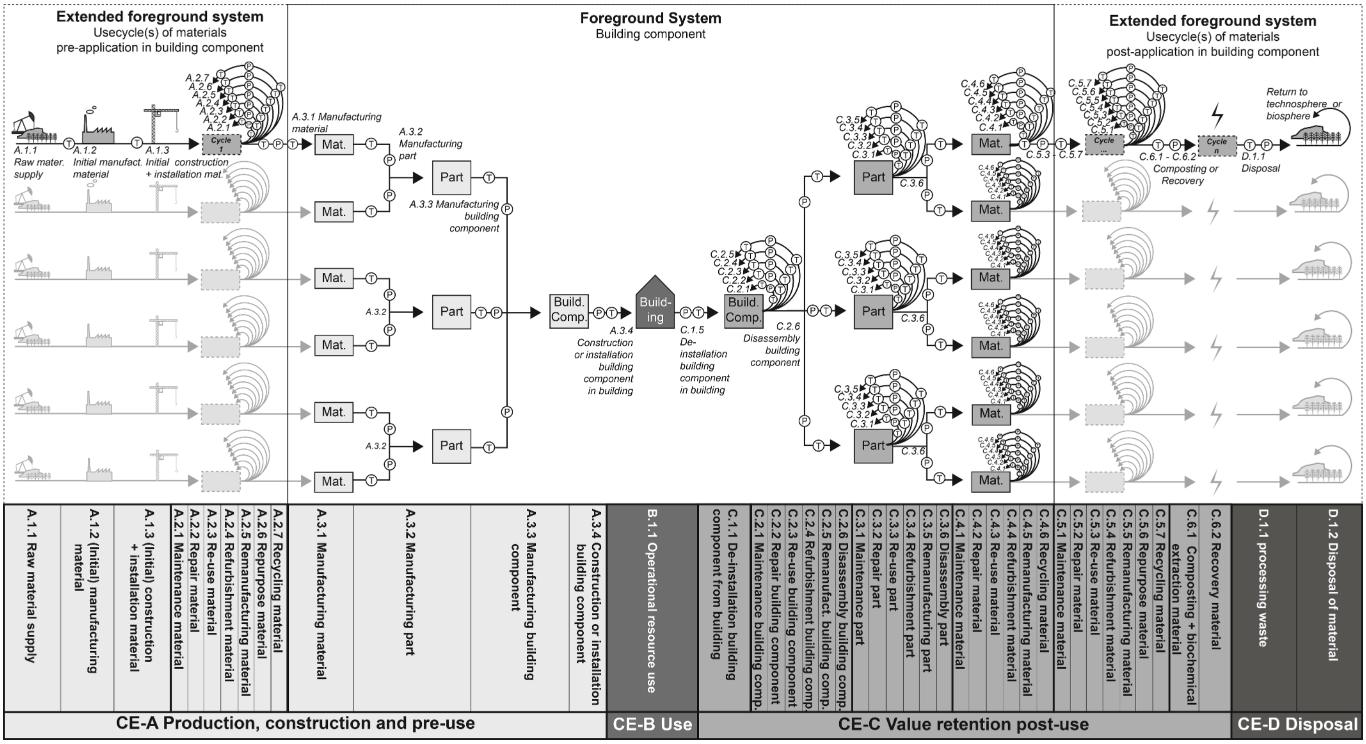


Fig. 3. CE-LCI Model.

short-cycling parts and materials when re-use and recycling avoids primary production of the same 'thing', applying the same processes, an equal distribution of impacts between all cycles could be reasonable (and simple). A condition is that quality or value should be retained throughout cycles. For example, for kitchens in which cabinets are re-used twice, we could assume that for every cabinet only one-third of material is virgin. On the other hand, CE LD allocation is preferable when the building component, part or material is cascaded into something else (i.e., the value between cycles is not the same). In such instances, equal distribution between all cycles is undesirable and it becomes necessary to distinguish which cycle a building component, part or material is in. Furthermore, CE LD is more suitable for long-cycling parts and materials, when it becomes less certain if, and what, impacts are avoided in the future.

In the CE-LCIA, the fraction of impact of the circular building component system allocated to the assessed building component is captured with parameter 'allocation fraction' (Af). In appendix 1, we explain how to determine Af using an equal distribution or CE LD approach.

4.3.2. *Impact calculation*

The impact calculation follows the hierarchy of the CE-LCI model: in a series of sums, the impacts on each building component system level are added to determine the impact of the assessed building component.

The total impact of a building component is calculated using Eq. (1):

$$I_{building\ component,x} = \sum_{k=1}^{n_1} I_{part,\ k} = I_{part,1} + I_{part,2} + I_{part,3} + \ldots + I_{part,n_1-2} + I_{part,n_1-1} + I_{part,n_1} \tag{1}$$

which is the sum of the impacts of all its parts, where n_1 is the number of parts in this building component. Likewise, the impact of a part is the sum of the impacts of all the materials, where n_2 is the number of materials with different use cycles and a different lifespan. The impact of a part can be calculated using Eq. (2):

$$I_{part,y} = \sum_{l=1}^{n_2} I_{material,\ l} = I_{material,1} + I_{material,2} + I_{material,3} + \ldots + I_{material,n_2-2} + I_{material,n_2-1} + I_{material,n_2} \tag{2}$$

To calculate the impact of a material *($I_{material,z}$)* for all the life cycle stages within that materials life cycle, allocated to the assessed building component during the RSP, we use Eq. (3):

$$I_{material,z} = \sum_{m=1}^{n_3} P_{life\ cycle\ stage,m} \cdot Af_{life\ cycle\ stage,\ m} \cdot AI_{life\ cycle\ stage,m} \cdot R_{\ life\ cycle\ stage,m} \tag{3}$$

where n_3 is the number of *different* life cycle stages (as defined in 4.1.3) for this material. P represents the probability of a life cycle stage to occur. Integrating a chance could be relevant for VRPs when assessing an *average* building component in a circular system. For example, in an EPD of a mass-produced circular façade, repair of parts might only occur for x% of the building components. The allocation fraction (Af) is the fraction of impact of a life cycle stage which is allocated to the material in the use cycle of the assessed building component. AI represents the *absolute* environmental impacts (i.e., before allocation) from completing a life cycle stage once. For example, to determine how much impact of a future remanufacturing cycle is allocated to the assessed building component, we need to know the *absolute* impact of the remanufacturing cycle. This is a sum of *absolute* impacts of the material, transport, process and energy in this life cycle stage as described in Eq. (4):

$$AI_{lifecycle\ stage} = AI_{materials} + AI_{transport} + AI_{process} + AI_{energy} \tag{4}$$

In Eq. (3), R is the rate – the number of times – in which a life cycle stage occurs in the RSP and following chain of cycles of the material. To find R for a life cycle stage of a material, relevant R values on each building component level need to be multiplied as shown in Eq. (5):

$$R_{life\ cycle\ stage} = R_{building\ component} \cdot R_{part} \cdot R_{material} \tag{5}$$

For example, to determine the remanufacturing-rate for the coating material of a kitchen, the replacement rates of the building component needs to be multiplied with the remanufacturing rate of the to-be-recoated parts. The rate of life cycle stages on different building levels can be determined using different equations. How often the assessed building component is replaced ($R_{building\ component}$) can be calculated by dividing the *RSP* by the leading lifespan ($L_{leading}$) of the building component using Eq. (6):

$$R_{building\ component,\ x} = \frac{RSP}{L_{leading,\ building\ component,x}} \tag{6}$$

Re-use takes place when the functional lifespan of a component, part or material is reached prior to its technical lifespan; the *R* for re-use can be calculated by dividing these. Note that 'one instance' might need to be subtracted, as VRPs often do not take place at installation, end of use or EoL. For example, the *R* for re-use of a part can be determined using Eq. (7):

$$R_{reuse,part} = \left(\frac{L_{technical,part}}{L_{functional,part}} - 1\right) \tag{7}$$

Repair, refurbishing and remanufacturing take place when the $L_{leading}$ of the higher system level is longer than that of the lower system level. For example, the *R* of repair of a part could be calculated as shown in Eq. (8):

$$R_{repair,part} = \left(\frac{L_{leading,building\ component}}{L_{leading,\ part}} - 1\right) \tag{8}$$

The $L_{leading}$ is determined differently for each VRP: for the repair, the $L_{leading}$ is equal to the technical lifespan whilst for refurbishment, the functional lifespan might be leading.

4.4. *Interpretation of results*

In phase 4 of an LCA, we interpret the results from the LCIA. A sensitivity analysis is needed to test the robustness of results and influence of assumptions, methods and data (Junnila and Horvath, 2003). Sensitivity analysis is not always included in building (component) LCAs. Common are sensitivity analysis of variations in grid mix, influence of material selection and lifespans. As CE-LCA includes all cycles on all building component system levels, additional analysis is needed. CE-LCA could be complemented with an LCA following EN 15804 (2012) and EN 15978 (2011) standards and/or the sensitivity of assumptions on the cycles could be tested.

4.4.1. *Sensitivity of number of cycles for each material applied in the building component*

The number of use cycles (N_{cycles}) for all materials applied in the building component is difficult to predict. N_{cycles} influences how much impact is allocated to the assessed building component (through parameter *Af*). If assumptions are optimistic, impacts might be spread over too many cycles and vice versa. So, the effects of adding or subtracting cycles should be tested. A distinction can be made between (1) known cycles, (2) likely past or future cycles, and (3) uncertain past or future cycles. The uncertainty is larger for cycles far into the future, for future cycles which are yet to be organised, when the partners who manufacture the building component are not involved in past or future cycles, or when materials are not traced through cycles (e.g., material passport). The analysis should focus on testing the most uncertain cycles.

4.4.2. *Sensitivity of the cycle number in which the material is in when applied in the building component*

If *Af* is determined using the CE LD approach (Eberhardt et al., 2020), the influence of varying the cycle number (C_{number}) should be tested. The C_{number} influences how much impact is allocated to the assessed building component (represented by parameter *Af*). For example, the impact allocated to cotton insulation is higher if the cotton had only one previous use cycle (e.g., fast fashion) than if it had three (e.g., as new clothing, second-hand clothing and cleaning cloths). Most relevant is to test materials with uncertain past cycles.

4.4.3. *Sensitivity of impact of the cycle*

The absolute impact of a life cycle stage is determined by the absolute impact of materials ($AI_{materials}$), transport ($AI_{transport}$), energy (AI_{energy}), and processes ($AI_{processes}$) of that life cycle stage. A cycle with a very low absolute impact is a local, direct, re-use cycle whilst (e.g.) remelting material at great distance has a much higher absolute impact. Correctly assuming the absolute impacts of each cycle – some far in the future – is trying. Additional sensitivity analysis could include varying amounts and types of processes, materials, energy and transport per cycle.

4.4.4. *Sensitivity of varying lifespans*

How often life cycle stages take place is expressed in *R*, which is influenced by the $L_{leading}$ of the material, part, and building component. The effects of varying the technical, functional or economic lifespan, or a combination should be tested. Consider a kitchen door which is re-used. If only the technical lifespan varies, the number of re-use cycles increases or reduces – resulting in a similar analysis as varying N_{cycles}. If only the functional lifespan is altered, more or fewer replacements of the door take place and the number of re-use cycles might increase or decrease proportionally. If both lifespans are increased or decreased in parallel, more or fewer (re)placements of the doors take place – whilst maintaining the same number of re-use cycles.

4.4.5. *Sensitivity of probability of a cycle*

P represents the probability that life cycle stages take place. A sensitivity analysis could determine the effect of varying the probability of (in particular) uncertain cycles.

5. Testing the CE-LCA model: the case of the circular kitchen

To test (and illustrate) the CE-LCA model, we compared the environmental impacts of two design variants of a Circular Kitchen (CIK) – to a business-as-usual (BAU) kitchen. First, we describe the kitchen variants (5.1). Following, we elaborate on the test following the CE-LCA phases: goal and scope definition (5.2), CE-LCI (5.3), CE-LCIA (5.4), and interpretation of the results (5.5).

5.1. *Description of the circular kitchen design variants*

We developed variants of the CIK in co-creation with Dutch industry partners and social housing associations. The housing associations are a logical primary target group owning 30% of the nation's housing stock; they have a substantial interest in implementing CE principles. Their kitchens are basic, have a similar layout and, usually, no appliances are provided. Therefore, the design variants focussed on redesign of the cabinetry. For each variant, the same countertops options were possible; therefore it was left outside of the scope of this assessment.

Fig. 4 visualises the technical models of the kitchen variants. The BAU kitchen represents the current practice. It is made of melamine-coated chipboard. Static joints are glued and movable joints are made with metal hinges and drawer slides. The kitchen is replaced every 20 years. The manufacturer sells the BAU kitchen to housing associations. Due to the low cost price, BAU kitchens are rarely repaired, refurbished, or re-used. At EoL, the kitchen is demolished and separated into waste flows. The chipboard is incinerated for energy recovery.

The 'Reclaim! kitchen' is based on substituting virgin materials with non-virgin alternatives. In this design variant, we assumed a similar technical, industrial and business model as the BAU kitchen. We assume

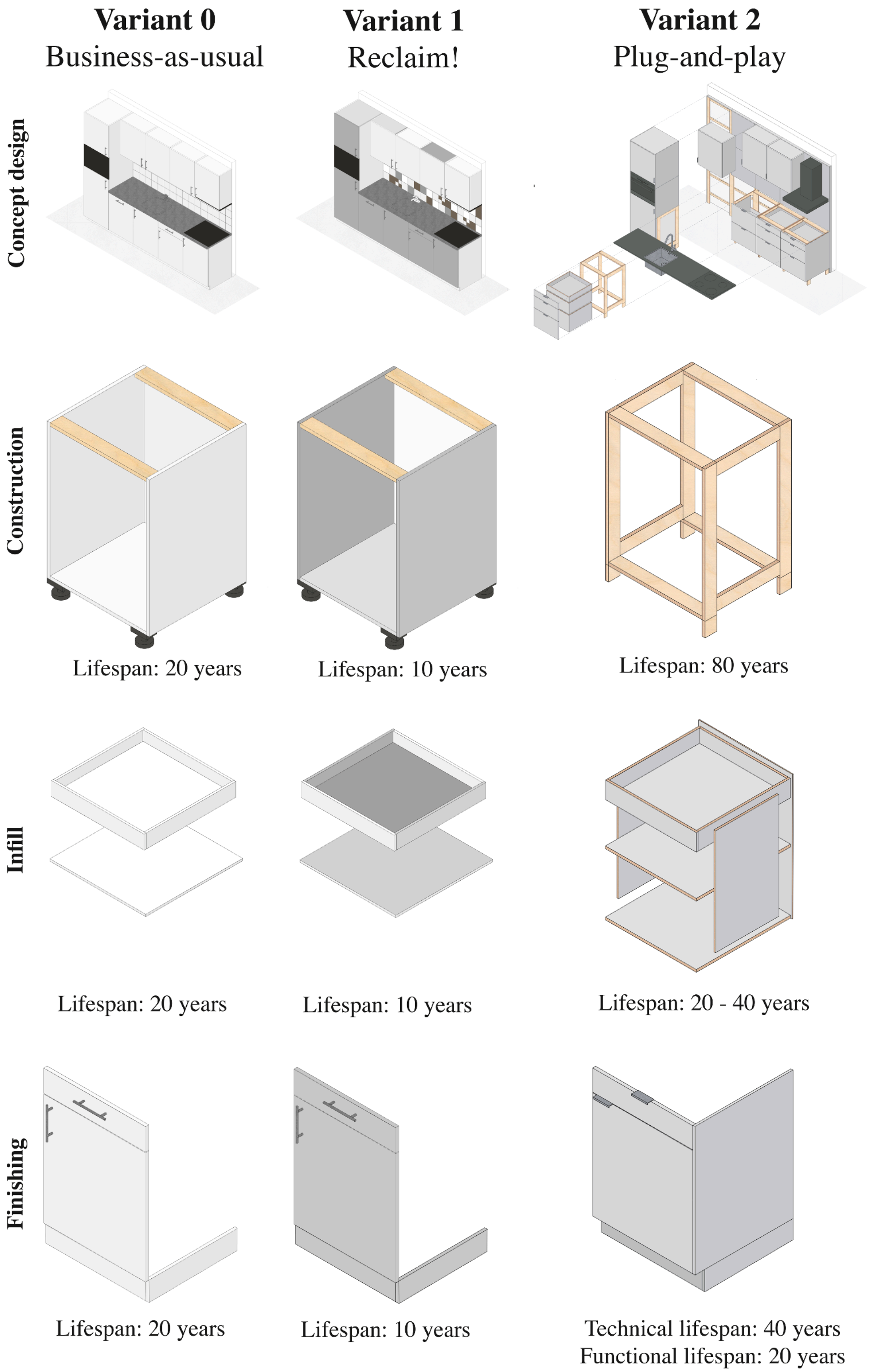


Fig. 4. Technical model of the design variants showing materialisation and lifespan.

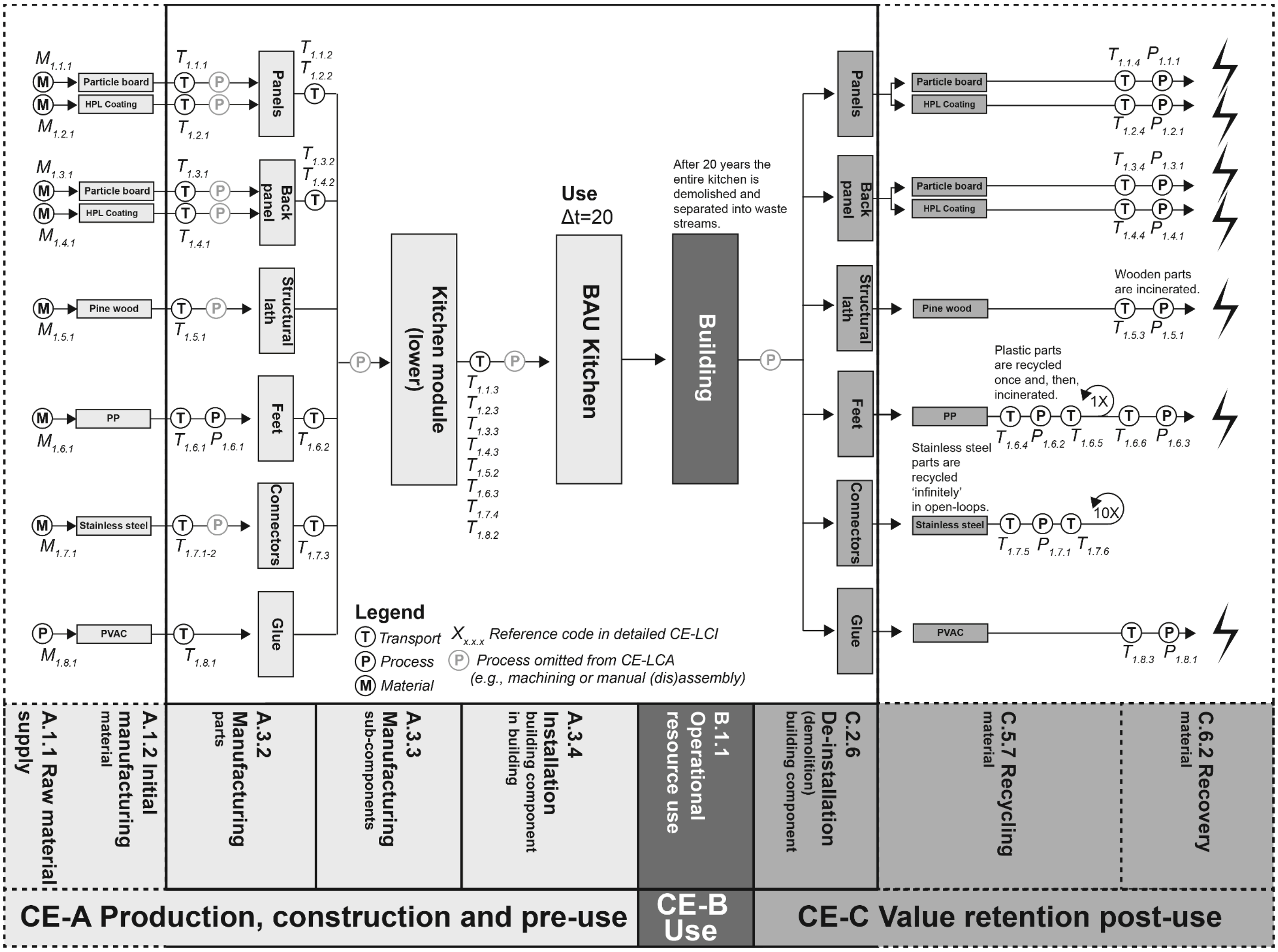


Fig. 5a. Simplified CE-LCI flowchart of the BAU kitchen.

the materials are directly re-used (i.e., in a secondary use cycle) and have a reduced lifespan of 10 years.

The Plug-and-Play (P&P) kitchen slows and closes loops by combining circular design strategies. It is a modular design, in which parts are separated based on their functional and technical lifespan. The cabinets consist of a construction (frame) with a long lifespan of 80 years. Infill parts, (e.g., drawers and shelves) have a medium lifespan between 20 and 40 years. The finishing parts (e.g., fronts) have shorter use cycles of 20 years. Parts are joint with de- and remountable connections, which facilitate future adjustments and re-use. The kitchen is made from plywood, to allow for a longer technical lifespan and multiple use cycles of parts. The kitchen manufacturer sells the kitchen to housing associations with a take-back guarantee and maintenance subscription. Extra kitchen modules and finishing-updates are offered to tenants through lease and sale-with-deposit contracts. At end of use, returned parts are sorted locally, to be re-used or sent back to the kitchen manufacturer where they are sorted to be remanufactured, recycled or recovered.

5.2. *Test of CE-LCA model: goal and scope definition*

We compared the environmental impacts of the CIK variants and the BAU variant. The functional unit was '*the use of a specific configuration of a lower kitchen cabinet in a circular system over a period of 80 years*'. The system boundary included life cycle stages CE-A to CE-D (as defined in 4.1.3). Yet, none of the variants had processes in stage CE-B and CE-D. In the foreground system, we excluded capital goods.

5.3. *Test of CE-LCA model: CE-LCI*

The CIK design variants were developed to the level of concept or prototype. As these remain 'theoretical' designs for which suppliers and VRP-partners were unknown, estimations were made on transport distances, production, VRPs and disposal processes. We also estimated the number of use cycles, and functional and technical lifespans. The assumptions were based on the expectations on how various circular design strategies could perform (compared to the BAU variant). For example, if directly re-used materials were applied in the Reclaim! variant, we expect a lower technical lifespan than in the BAU kitchen. Additionally, the assumptions were based on experience of the housing associations and industry partners involved in the development. Furthermore, assumptions were aligned between variants (e.g., similar distance between manufacturer and user, similar recycling scenarios). For materials recycled in infinite 'open loops', we set N_{cycles} at 10.

The CE-LCI of each design variant has been summarised in a flowchart (see Fig. 5a-c). See appendix 2, for the detailed CE-LCI.

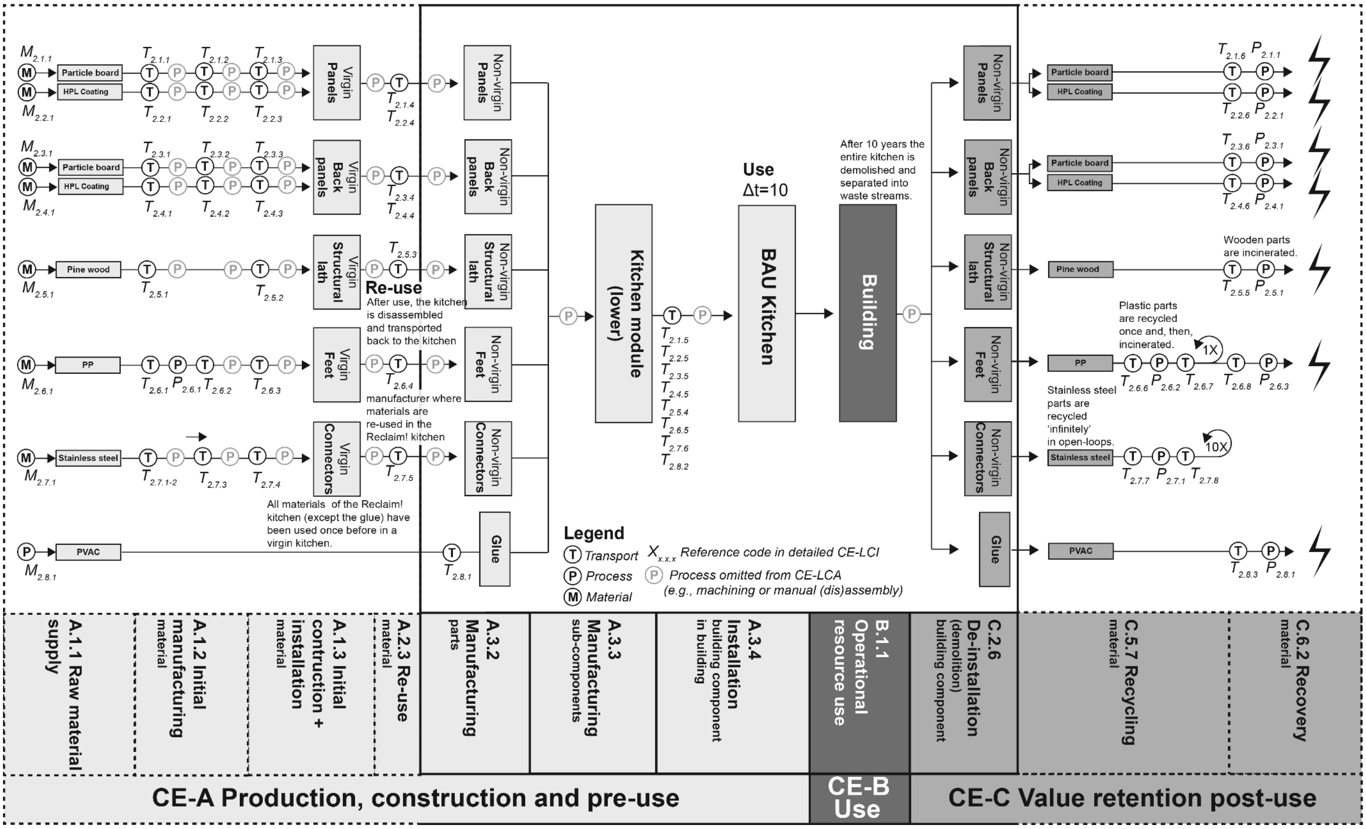


Fig. 5b. Simplified CE-LCI flowchart of the Reclaim! kitchen.

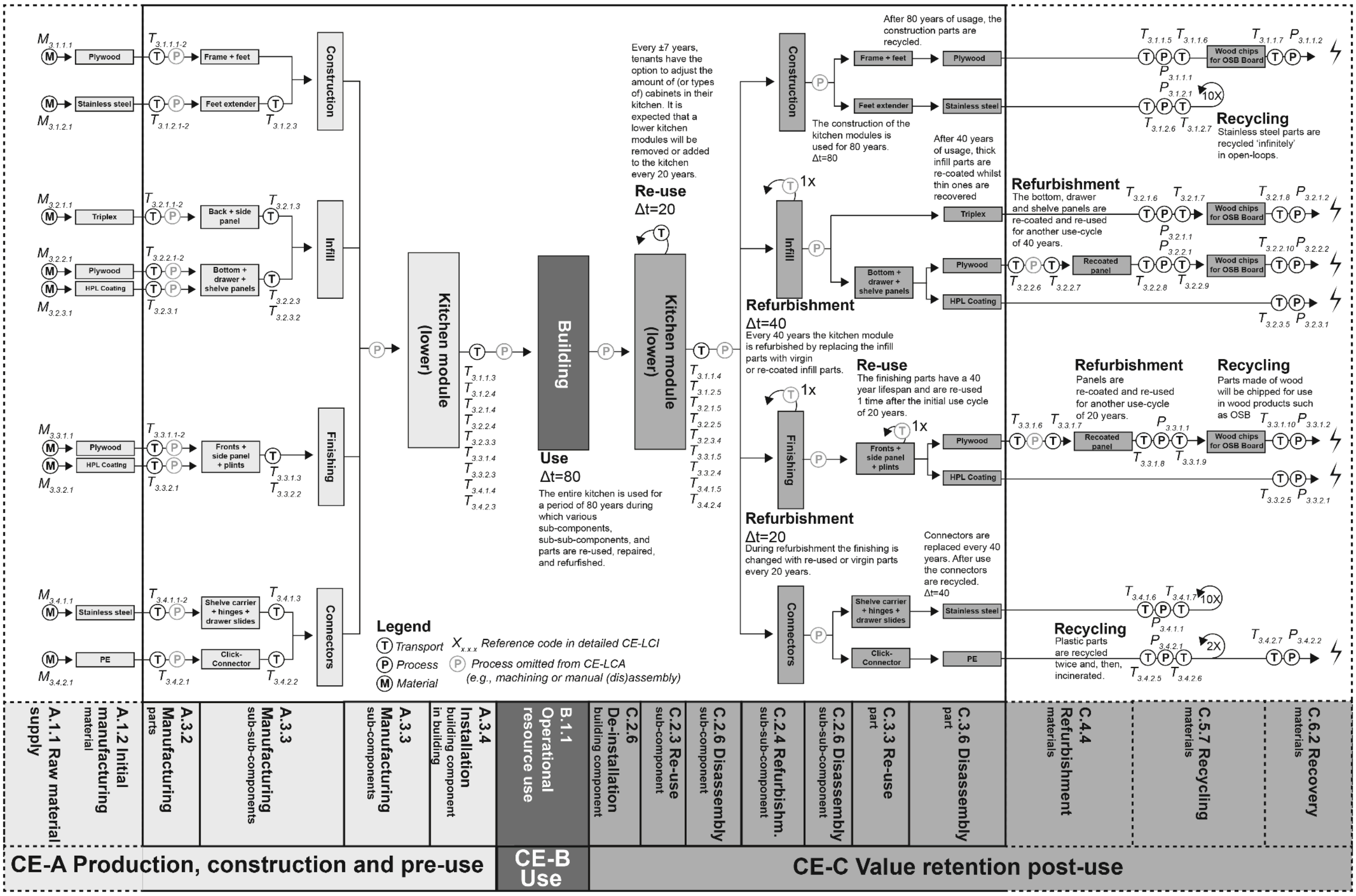


Fig. 5c. CE-LCI flowchart of the P&P kitchen.

Table 1
CE-LCIA results for the BAU and CIK variants over 80 years

		BAU	Reclaim!		P&P	
Impact category	**Unit**	**Baseline**	**Baseline**	**Savings to BAU [%]**	**Baseline**	**Savings to BAU [%]**
Global warming potential	kg CO2 eq	1,48E+02	1,50E+02	-1%	6,40E+01	57%
Ozone layer depletion potential	kg CFC-11 eq	1,32E-05	1,12E-05	15%	6,92E-06	48%
Photochemical oxidation potential	kg C2H4 eq	5,10E-02	4,71E-02	7%	2,54E-02	50%
Acidification potential	kg SO2 eq	5,99E-01	5,34E-01	11%	2,99E-01	50%
Eutrophication potential	kg PO4--- eq	2,22E-01	1,98E-01	11%	1,05E-01	53%
Abiotic depletion potential for elements	kg Sb eq	1,55E-03	1,24E-03	20%	9,77E-04	37%
Abiotic depletion potential for fossil fuels	MJ	1,81E+03	1,56E+03	14%	7,88E+02	56%
Fresh water aquatic ecotoxicity potential	kg 1,4-DB eq	8,30E+01	9,37E+01	-13%	3,73E+01	55%
Human toxicity potential	kg 1,4-DB eq	1,82E+02	2,37E+02	-30%	9,11E+01	50%
Marine aquatic ecotoxicity potential	kg 1,4-DB eq	1,70E+05	1,71E+05	-1%	7,62E+04	55%
Terrestrial ecotoxicity potential	kg 1,4-DB eq	4,93E-01	4,94E-01	0%	2,81E-01	43%

Note: The colour shows a gradient between the highest (red) and lowest (green) value per impact category.

5.4. *Test of CE-LCA model: CE-LCIA*

The CE-LCIs were modelled in openLCA version 1.9 software; the background system was modelled with the Ecoinvent 3.4 APOS database (Wernet et al., 2016), using system processes to get aggregated results. The CE-LCIA was calculated using characterization factors from the Centre for Environmental Studies (CML)-IA baseline (Guinée et al., 2001). CML includes 11 environmental, resource-depletion and toxicology midpoint impact categories and is commonly used by the building sector. We excluded biogenic carbon (e.g., in wood) from the impact assessment. As we consider all cycles, it is assumed that carbon uptake equals carbon emission over the lifecycle of the material; we question the fairness to give first cycles a benefit from carbon uptake occurring prior to initial use cycles. Therefore, we applied the '0–0 rule' to biogenic carbon. The CE-LCIA parameters were determined for each material (see appendix 3). The value differs between cycles, so we applied the CE LD approach to determine Af. As the object of assessment was a *specific* configuration of a lower kitchen cabinet, P is set at 1: each inventoried VRP is assumed to occur.

The results of the CE-LCIA are summarised in Table 1. The Reclaim! kitchen has a lower environmental impact than the BAU on 6 of the 11 impact categories. P&P realises a significant impact reduction in all indicators in comparison to the BAU case. We refer to appendix 4 for further analysis on the impact distribution between 'production, construction and pre-use' and 'value retention post-use', allocation of impacts to the kitchen over the RSP, and the distribution of impacts between use cycles of materials applied in the kitchen over time.

5.5. *Test of CE-LCA model: interpretations of the results*

For the purpose of testing and illustrating the CE-LCA model, we extensively tested the sensitivity of assumptions on cycles. Comparing CE-LCA (using CE LD allocation) to an LCA following the EN 15978 (2011) and EN 15804 (2012) standards was not part of the scope of this study. We refer to Eberhardt (2020) for such a comparison.

Testing the effects of the following 'what if' questions was considered most relevant for the kitchens: what if the kitchens are re-used (more); what if the future cycles of the P&P kitchen are not realised; what if the kitchens are used longer or shorter; what if the finishing of the P&P kitchen is exchanged more or less often? Following these questions, we analysed the sensitivity of varying N_{cycles} and lifespans of (parts of) the kitchen variants. A detailed description of all sensitivity scenarios is included in appendix 5.

We analysed the sensitivity of the N_{cycles} by adding one cycle ('$C+1'$'), two cycles ('$C+2'$') and subtracting (up to) three cycles ('C-1′', 'C-2′', 'C-3′') from the baseline scenario. When cycles were added, we assumed local, direct re-use for the entire kitchen cabinet; when cycles were subtracted, we removed the 'outer' cycles (i.e., recycling) first, followed by remanufacturing and re-use, respectively. Only the industry standard incineration for energy recovery and open-loop recycling were retained. For the P&P kitchen, scenario 'C-3′' can be considered a linear scenario.

We tested the sensitivity varying $L_{functional}$ and $L_{technical}$ of (parts of) the kitchen variants. In the BAU and Reclaim! kitchen, all parts have the same lifespan and the $L_{functional}$ and $L_{technical}$ are equal. Any changes to either results in the replacement of the entire kitchen. On the other hand, P&P kitchen parts have different lifespans and $L_{technical}$ of finishing parts is longer than $L_{functional}$. So, we varied both $L_{functional}$ of finishing parts and $L_{functional}$ and $L_{technical}$ of all parts in parallel. To make the scenarios comparable, lifespans were varied between ±7 and 80 years. Note that such a long lifespan is unlikely for the BAU and Reclaim! kitchens as their materials have shorter lifespans, and these kitchens are not adaptable.

5.5.1. *Results of the sensitivity analysis*

The results of the sensitivity analysis are included in appendix 6. Table 2 summarizes the percentual savings of each scenario compared to the baseline scenario of the same design variant.

For the BAU, adding two cycles ($C+2$) reduced impacts between 31% and 47% compared to its baseline scenario; for the Reclaim! kitchen, the reduction is only between 10% and 20%. The deviation is less as the difference between Af is larger when adding a re-use cycle to virgin material then to material in a second use cycle. From the P&P variant we found that additional cycles do not necessarily lead to less allocated impact: removing the outer recycling processes in scenario C-1 resulted in impact savings between −4% and 73% compared to the baseline scenario. So, adding cycles with relatively high impact processes does not reduce impacts. The most beneficial cycles are the direct, local re-use cycles of scenarios $C+1$ and $C+2$ which lead to significant savings in all variants on all impact categories.

We found that varying $L_{functional}$ and $L_{technical}$ in parallel results in significant deviations from the baseline scenarios: a proportional relationship is visible. For the P&P, we found that only varying $L_{functional}$ is less impactful: although more finishing parts need to be placed (i.e., R increases), they are also re-used more often. Therefore, the Af of finishing parts decreases and less impact is allocated to the kitchen. If all variants are compared on a 20-year $L_{technical}$ (see appendix 6, Table A6.2), the Reclaim! variant decreases environmental impacts between 35%–60% compared to the BAU. The P&P results in a −38% to 10% reduction compared to the BAU. This has two reasons: finishing parts are still replaced every 10 years; the circular design principle of the P&P design – facilitating partial replacements to keep the whole of the kitchen in use longer – is nullified in this scenario.

Table 2
Percentual reduction per scenario compared to the baseline scenario of that design variant

	BAU						Reclaim!						
Impact category	**Baseline**	**C+1**	**C+2**	**L7**	**L40**	**L80**	**Baseline**	**C+1**	**C+2**	**L7**	**L20**	**L40**	**L80**
Global warming potential	0%	30%	44%	-200%	50%	75%	0%	7%	19%	-50%	50%	75%	88%
Ozone layer depletion potential	0%	32%	47%	-200%	50%	75%	0%	1%	11%	-50%	50%	75%	88%
Photochemical oxidation potential	0%	29%	42%	-200%	50%	75%	0%	1%	12%	-50%	50%	75%	88%
Acidification potential	0%	30%	45%	-200%	50%	75%	0%	3%	13%	-50%	50%	75%	88%
Eutrophication potential	0%	30%	45%	-200%	50%	75%	0%	3%	14%	-50%	50%	75%	88%
Abiotic depletion potential for elements	0%	31%	46%	-200%	50%	75%	0%	2%	10%	-50%	50%	75%	88%
Abiotic depletion potential for fossil fuels	0%	31%	46%	-200%	50%	75%	0%	3%	13%	-50%	50%	75%	88%
Fresh water aquatic ecotoxicity potential	0%	27%	40%	-200%	50%	75%	0%	10%	20%	-50%	50%	75%	88%
Human toxicity potential	0%	21%	31%	-200%	50%	75%	0%	6%	14%	-50%	50%	75%	88%
Marine aquatic ecotoxicity potential	0%	29%	43%	-200%	50%	75%	0%	7%	18%	-50%	50%	75%	88%
Terrestrial ecotoxicity potential	0%	27%	40%	-200%	50%	75%	0%	4%	12%	-50%	50%	75%	88%

Note: The colour shows a gradient between the highest percentual savings (green) and lowest percentual savings (red) for all scenarios per design variant, per impact category.

	P&P										
Impact category	**Baseline**	**C-3**	**C-2**	**C-1**	**C+1**	**C+2**	**Lf=80-40-7-40, Lt=80-40-40-40**	**Lf=80-40-40-40, Lt=80-40-40-40**	**Lt=7-7-7-7, Lf=7-7-3,5-7**	**Lt=20-20-20-20, Lf=20-20-10-20**	**Lt=40-20-20-20, Lf=40-20-10-20**	**Lt=80-80-80-80, Lf=80-80-40-80**
Global warming potential	0%	-49%	-12%	3%	18%	30%	-23%	22%	-527%	-109%	-99%	47%
Ozone layer depletion potential	0%	-71%	-24%	-4%	18%	31%	-25%	25%	-527%	-109%	-99%	46%
Photochemical oxidation potential	0%	-65%	-23%	-3%	17%	28%	-21%	21%	-532%	-111%	-100%	46%
Acidification potential	0%	-62%	-19%	-1%	18%	29%	-23%	22%	-531%	-110%	-100%	46%
Eutrophication potential	0%	-55%	-16%	2%	17%	29%	-23%	22%	-533%	-111%	-100%	46%
Abiotic depletion potential for elements	0%	61%	69%	73%	16%	27%	-37%	23%	-556%	-119%	-100%	45%
Abiotic depletion potential for fossil fuels	0%	-61%	-18%	-1%	18%	30%	-23%	23%	-528%	-109%	-99%	46%
Fresh water aquatic ecotoxicity potential	0%	-3%	16%	23%	17%	27%	-22%	18%	-540%	-113%	-100%	46%
Human toxicity potential	0%	-7%	5%	10%	14%	22%	-12%	10%	-545%	-115%	-100%	46%
Marine aquatic ecotoxicity potential	0%	-12%	13%	24%	17%	28%	-24%	20%	-538%	-113%	-100%	46%
Terrestrial ecotoxicity potential	0%	-26%	3%	16%	16%	27%	-23%	19%	-540%	-113%	-100%	46%

Note: The colour shows a gradient between the highest percentual savings (green) and lowest percentual savings (red) for all scenarios per design variant, per impact category.

5.5.2. *Conclusions from the CE-LCA*

From the CE-LCIA and sensitivity analyses, we conclude the following: First, applying non-virgin material, can reduce the environmental impact. However, if the lifespan of the kitchen is reduced – resulting in a higher replacement rate – reductions in impact can be nullified. Additionally, the impacts of initial production and construction of non-virgin materials remain visible, so using non-virgin is less attractive if these materials had a high(er) initial production and construction impact. Second, facilitating multiple cycles results in a lower (allocated) environmental impact, particularly for direct, local re-use cycles. High-impact recycling cycles are less attractive. Third, we found that the P&P kitchen resulted in the least environmental impacts through longer use of parts, introducing more use-cycles of components, parts and materials and facilitating partial replacement of parts. Yet further environmental impact reduction is possible by combining variants: a P&P kitchen in which non-virgin materials are applied, but only if these materials do not lower the technical lifespan of the kitchen.

6. Evaluation of the CE-LCA model

In 10 semi-structured expert sessions, we evaluated the CE-LCA model with 44 experts and practitioners from academia, industry and government in the field of LCA, circular design, and the circular built environment. The CE-LCA model was presented and the following questions were asked: what are your initial impressions on the CE-LCA model; what are the potential (dis)advantages; how would you improve the model? The answers and discussion following these questions were documented in minutes and analysed using an emergent coding technique (Dahlsrud, 2008; Kirchherr et al., 2017).

Table 3 shows the resulting advantages, disadvantages and improvement points of the CE-LCA model.

The experts and practitioners acknowledged the challenges in capturing the environmental burdens and benefits of the CE concept applying EN 15978 (2011) and EN 15804 (2012). They saw the ability to assess multiple cycles as a main advantage of the CE-LCA model. They found that CE-LCA incentivises narrowing, slowing and closing cycles, not only today but also in the future; CE-LCA moves LCA away from a linear "efficiency" focus to a more ideal circular mindset. CE-LCA was considered more suitable in ex-ante assessments in which 'theoretical', multi-cycling scenarios are explored to identify 'ideal' circular building components. For example, in the context of design or policy making.

The experts and practitioners suggested CE-LCA in ex-ante, ex-post and certification assessments in practice poses challenges that will require further development and rigorous testing. Determining all use cycles on all levels of a building component is complex: it extends beyond the control of building component manufacturers and the scope of building projects. Including multiple cycles – some far into the future – increases uncertainty. Burdens could be shifted to cycles which might not come to pass, making CE-LCA sensitive to misuse. Furthermore, including future cycles might undermine efforts to reduce impacts *today*. Therefore, several experts posed the EN15804 and EN15978 approach remains preferable. If applied, the experts and practitioners suggested CE-LCA should be combined with extensive sensitivity analysis, include peer reviewing, and/or be done in parallel with a 'standard' LCA.

The majority of the improvement opportunities were concerned with reducing uncertainty, preventing misuse, and improving ease of use and implementation. To refine the accuracy of CE-LCA, the experts posed to differentiate between types of cycles, such as known or unknown cycles, certain or uncertain cycles, short-term or long-term cycles, open or closed cycles, and equal-value or downgrading cycles. Different types of cycles could benefit from different allocation approaches. Additionally, factors for material quality and the market situation could be included in the allocation approach. The experts and practitioners suggested to develop templates and regulations for cycles to reduce the complexity and ensure fair use. Finally, several experts stressed that circular assessment encompasses more than environmental impact assessment, and should include value, costs, material flows, and/or social performance criteria. If and how improvement points were implemented in the CE-LCA model is shown in column 3 of Table 3.

7. Discussion and conclusion

In this paper, we explored how multiple cycles could be included in the LCA of building components by developing and testing a Circular Economy Life Cycle Assessment (CE-LCA) model for building components. This model builds on existing LCA standards applied in the building sector (EN15804 and EN15978). In CE-LCA, building components are considered as a composite of parts and materials with different and multiple use cycles; the system boundary is extended to include Value Retention Processes on all building component system levels, both

Table 3
Evaluation of the CE-LCA model in 10 expert session.

	Category	Remarks	Implementation of improvements
Advantages	**Applicability**	Suitable for ex-ante assessment (e.g., in policymaking, early-stage design)	
		Suitable to assess multiple cycles	
		Most suitable for (reproducible) building component or product level	
		Supports determining more ideal CE (e.g., ideal vision for back-casting)	
		Also suitable when materials cannot be re-used or recycled at same value	
	Incentives CE	Method incentivises not only narrowing, but also slowing and (high-value) closing cycles	
	Levels	CE-LCA introduces 'missing' building component level in LCA	
	Fair accounting impacts	The linear degressive method divides burden fairly between cycles; no double crediting possible	
		All cycles are included; impacts from other cycles (e.g., production, disposal) remain visible in all cycles	
	Ease of use	The allocation formula is understandable and transparent (more than the PEF)	
	Instrument for discussion	Method stimulates (re)discussing problems and incentives in current LCA standards	
		Method shows how we could include CE in LCA	
		Method shows how complex CE in design and the built environment is	
Disadvantages	**Non-applicability**	Less suitable for ex-post assessments and certification	
		Less suitable for building scale (too complex, uncertain, no control by producing supply chain)	
	Uncertainty in assumptions	Difficult to determine and guarantee future cycles; leads to not-accurate results	
		Uncertainty in assumptions far in the future (cycles, processes, energy mix are unknown)	
		Sensitive to assumptions on functional, technical and economic lifespan	
	Greenwashing impacts	Burdens can be shifted towards [non-existent] cycles in the future, diluting impacts	
		Easy to mis-use by industry by adding future cycles	
	Challenging to implement	Requires transition in building industry to determine all cycles (i.e., from one-off projects to a (closed-loop) component-wise industry)	
		Difficult to implement a new LCA methods in practice, it is easier to adapt the current LCA standard	
		All cycles need to be documented and kept tracible over long-term (e.g., government regulation is needed)	
		Current LCA tools in practice cannot do a CE-LCA calculation	
	Difficulties in use	Method is complex	
		Method is time consuming	
	Urgency	Virgin production burdens should be in first cycles to reduce our impacts now	
Improvements	**Improvements ease of use**	Make the method understandable and simple to use, (e.g., include a manual, concrete examples, clarify terms, single indicator system)	Method has been described extensively in paper including description of terms and concrete examples
		Make method affordable and fast to use	Challenges relevant for all LCAs - not addressed in this paper
		Provide (more) background data; make data accessible to industry	Challenges relevant for all LCAs - not addressed in this paper
		Shift burden of proof for CE-LCA from building level to component level (i.e., component-EPD's)	The scope of CE-LCA has been shifted from buildings to building components
		Translate to a design synthesis tool (e.g., guidelines, flowchart) and practice assessment tool	Future research could focus on measuring different building components to develop design guidelines: Direction for future research included in discussion
	Improvement accuracy and certainty in allocation approach	Differentiate between different objects of assessment in CE-LCA	We distinguished 'average' and 'specific' building components in a circular system as objects of assessment
		Differentiate different cycles (i.e., known or unknown, high-value or low-value, open or closed)	Section 4.3.1 states different allocation approaches should be used for different types of cycles
		Prefer mLCA approach (i.e., equal distribution) for known cycles, mass production, direct re-use and recycling	Section 4.3.1 suggests different allocation approaches have merit in different instances: equal distribution approach should be preferred in instances mentioned on the left
		Include market situation and material quality factors in allocation approach	Direction for future research mentioned in Section 6
		Add probability factor for cycles to CE-LCA	Probability factor was included in equation 3
		Include (use) time in allocation approach	

(*continued on next page*)

Table 3 (*continued*)

Category	Remarks	Implementation of improvements
		Use time was included in equation A1.1b (equal distribution approach). Use time is not yet included in the CE-LD approach: direction for future research included in Section 7
Improvement ease of implementation in practice	Differentiate LCA levels (do not interlink them)	One of the requirements for CE-LCA is considering the link between levels of the building. However, the scope of CE-LCA has been limited to building components instead of buildings as a whole
	Develop rules, template or regulation for cycles (i.e., amount, division of impact, types of cycles, system boundary)	Direction for future research mentioned in Section 7
	Prefer an LCA 'tax' system: producer takes initial production and EOL impacts; cycles can be added over time	Proposed tax approach was considered unfavourable to incentivise design for multiple future cycles - comment was not further included in the CE-LCA model
	Test the method in a real-life case with stakeholders	Direction for future research mentioned in Section 7
Improvement of certainty and prevention of misuse	Use CE-LCA as an additional informational module "circular potential" next to standard LCA	Suggestion is mentioned in Section 7
	Obligatory peer review of CE-LCA	Suggestion is mentioned in Section 6
	Include a sensitivity analysis on influence of varying future cycles	Use of and need for sensitivity analysis in CE-LCA is discussed in Sections 4.4 and 6
Widen scope CE assessment	Assessment on other criteria should be part of CE assessment (i.e., value, costs, material flow, social factors)	Direction for future research mentioned in Sections 6 and 7

in- and outside of the assessed building component; the impacts of all cycles can be divided using an 'equal distribution' or CE LD allocation approach. The model has been tested in the case of the Circular Kitchen and evaluated with 44 experts.

Our findings corroborate Allacker et al. (2017): including multiple cycles within the scope of the assessed product results in the best 'physical realism' for multi-cycling products [or building components] within the circular system. Like Eberhardt et al. (2021), we found the CE-LCA approach suitable in ex-ante assessments in which 'theoretical' scenarios are explored to identify 'ideal' circular building components. However – as concluded by Allacker et al. (2017), De Wolf et al. (2020) and Eberhardt et al. (2021) – we found that all cycles of the building component system are difficult to determine in a practice setting; this increases uncertainty, makes the approach sensitive to mis-use and could hinder reducing environmental impacts both in the short and long term.

Yet, our recommendation differs from Allacker et al. (2017). They suggested to not include all cycles; we suggest that applying CE-LCA, or equivalent multi-cycling LCA, is necessary to transition to a 'truly' circular built environment. Without including all cycles within the assessment, we cannot get an accurate overview of the burdens and benefits of circularity. Yet, we urge the utmost care with CE-LCA in practice. We propose two pathways to manage the disadvantages of CE-LCA. First, the CE-LCA approach could be developed further to reduce uncertainty, improve accuracy, usability and fair-use: the CE LD allocation approach does not yet incorporate length of use cycles; regulations (or 'templates') on how to approach various types of cycles for different materials could be developed; CE-LCA should be tested with industry. Alternatively, LCA which does not include all cycles could be optimised to incentivise narrowing, slowing and closing (all) cycles now and in the future. Consider, for example, the 'Circular Footprint Formula' as part of the Product Environmental Footprint method (Zampori and Pant, 2019). Yet, blending approaches could also increase complexity and cloud the (dis)advantages of each approach. A second pathway is to exercise awareness of the value and limitations of CE-LCA and use the model appropriately. A CE-LCA should include extensive sensitivity analysis and/or could be done in parallel to standard LCA – functioning as a 'circular potential' informational module. To increase transparency within reporting, the distribution of impacts between cycles could be reported (in line with De Wolf et al. (2020)).

Future research could also focus on CE-LCA for the building level. Although, the testcase in this paper does not support building CE-LCA, theoretically, this model could be applied to buildings. Especially if the building is considered as a composite of building components. Undoubtedly, this increases the complexity of CE-LCA. Additionally, more knowledge is needed on which design variants for circular buildings and components perform best environmentally to support the transition to a 'truly' circular built environment. Finally, this research focused on environmental impact assessment in a CE. Yet, holistic CE assessment should include more criteria. Future research could focus on combining CE-LCA with Material Flow Analysis (MFA), (functional) value and economic performance assessment (e.g., through CE Life Cycle Costing (Wouterszoon Jansen et al., 2020)).

We conclude that the CE-LCA model can successfully support LCAs of circular building components – especially in theoretical setting; the step-by-step description of the model and example case can provide practical guidance for future assessments. However, we see the presented model not as a 'ready for practice' approach to LCA of circular building components, but rather as a tool for further research and discussion. As such it makes an important step to support the assessment of circularity in the built environment and, subsequently, to the transition to a CE in the built environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Determining the allocation fraction in CE-LCA using an equal distribution or CE LD allocation approach

In this appendix we explain how to determine the allocation fraction – parameter Af – in a Circular Economy Life Cycle Assessment (CE-LCA) of a building component following an equal distribution approach or using the Circular Economy Linearly Degressive (CE LD) approach (Eberhardt et al., 2020). As discussed in section 3.4.1 of this paper, Af determines the fraction of impact of the building component system that is allocated to the assessed building component. In CE-LCA, the impacts are calculated on material level using Eq. (3). There, the Af specifies how much impact of each lifecycle stage within a material's life cycle is allocated to the use cycle where the material is applied in the assessed building component.

A1.1. Equal distribution approach

Af is influenced by the total number of use cycles within a material's lifecycle, captured by parameter N_{cycles} . For example, before wood is applied in the assessed building component – a façade – it had a previous use cycle in another building (use cycle 1); after use in the façade (use cycle 2), the wood is chipped for OSB production (use cycle 3); after that use cycle, the wood is incinerated for energy production (use cycle 4). In this case the number of use cycles within the wood lifecycle (N_{cycles}) is 4. If impacts are distributed equally between cycles and we assume the cycles are of equal length, the value of Af equals a fraction of N_{cycles} (see equation A1.1a):

$$Af = \frac{1}{N_{cycles}} \tag{A1.1a}$$

If impacts are distributed equally and the cycles are not of equal length, the length of the current cycle $(\Delta t_{current\ cycle})$ can be divided by the length of all use cycles within the material's lifecycle $(\Delta t_{all\ cycles})$ using equation A1.1b.

$$Af = \frac{\Delta t_{current\ cycle}}{\Delta t_{all\ cycles}} \tag{A1.1b}$$

A1.2. Circular Economy Linearly Degressive approach

The CE LD approach divides impacts from initial production and construction (all life cycle stages before the first use), VRPs (all life cycle stages after first use and prior to disposal), and disposal differently. The majority share of the impact is allocated to the use cycle where the impacts occur. For the initial production and construction this is cycle number (C_{number}) 1. The share of impact allocated to subsequent cycles decreases linearly (see Fig. A1.1). For disposal impacts the majority share is allocated to the last cycle and impacts are allocated to previous cycles in a linearly degressive manner. The impacts of VRPs are allocated equally over all use cycles. Note that the impacts from initial production and construction, VRPs and disposal allocated per use cycles should add up to 100% of the impacts generated throughout the entire lifecycle (represented by the grey area in Figure A1.1). In other words, impacts over the entire lifecycle do not 'disappear'.

The CE LD approach consists of a series of equations: how the impacts are divided between cycles depends on two parameters. First, on the total number of use cycles within the materials lifecycle - parameter N_{cycles}. Second, a factor (F) determining how much more impact of initial production and construction should be allocated to the first cycle versus the last cycle; vice versa for the disposal impacts. To apply the CE LD approach in the CE-LCA of a building component, the Af of initial production and construction, VRPs and disposal of each material (with different use cycles) applied in the building component needs to be determined.

A.1.2.1. Determining the allocation fraction of initial production and construction impacts for a material

To calculate the amount of initial production and construction impacts allocated to each use cycle of a material (see Figure A1.1), equations A1.2-A1.5 can be applied. These equations were derived from Eberhardt et al. (2020, pp. 9 & Supplementary material S3).

The percentage of initial production and construction impacts of a materials allocated to its first use cycle (V_1) can be calculated using equation A1.2:

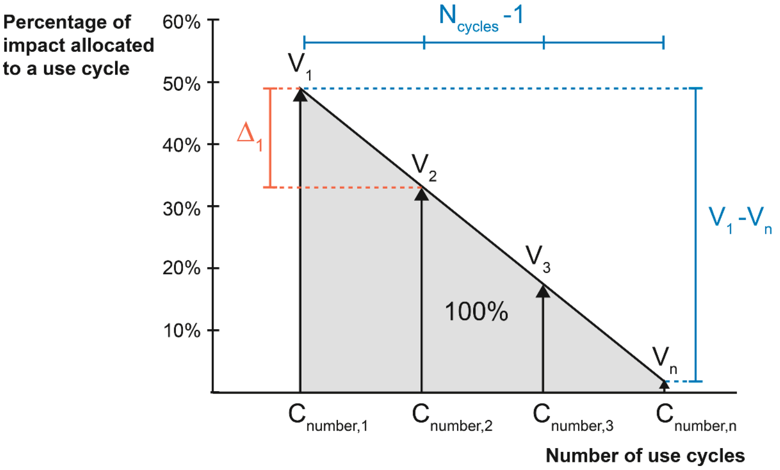


Fig. A1.1. Explanatory figure illustrating the CE LD equations to determine the percentage of impact of initial production and construction impacts allocated to each use cycle of a material (adapted from Eberhardt et al. (2020)).

Table A1.1
Precalculated CE LD allocation fractions for $F = 50$.

1	1	100%	N/A	100%
2	1	98%	50%	2%
	2	2%	50%	98%
3	1	65%	33%	1%
	2	33%	33%	33%
	3	1%	33%	65%
4	1	49%	25%	1%
	2	33%	25%	17%
	3	17%	25%	33%
	4	1%	25%	49%
5	1	39%	20%	1%
	2	30%	20%	10%
	3	20%	20%	20%
	4	10%	20%	30%
	5	1%	20%	39%
6	1	33%	17%	1%
	2	26%	17%	17%
	3	20%	17%	13%
	4	13%	17%	20%
	5	7%	17%	26%
	6	1%	17%	33%
7	1	28%	14%	1%
	2	23%	14%	5%
	3	19%	14%	10%
	4	14%	14%	14%
	5	10%	14%	19%
	6	5%	14%	23%
	7	1%	14%	28%
8	1	25%	13%	0%
	2	21%	13%	4%
	3	18%	13%	7%
	4	14%	13%	11%
	5	11%	13%	14%
	6	7%	13%	18%
	7	4%	13%	21%
	8	0%	13%	25%
9	1	22%	11%	0%
	2	19%	11%	3%
	3	16%	11%	6%
	4	14%	11%	8%
	5	11%	11%	11%
	6	8%	11%	14%
	7	6%	11%	16%
	8	3%	11%	19%
	9	0%	11%	22%
10	1	20%	10%	0%
	2	17%	10%	3%
	3	15%	10%	5%
	4	13%	10%	7%
	5	11%	10%	9%
	6	9%	10%	11%
	7	7%	10%	13%
	8	5%	10%	15%
	9	3%	10%	17%
	10	0%	10%	20%

The percentages in this table have been rounded of to the nearest whole number.

$$V_1 = \frac{2 \cdot F}{N_{cycles} \cdot (F+1)} \cdot 100\% \tag{A1.2}$$

Where F is the factor determining how much more impact is allocated to the first use cycle versus the last use cycle. Eberhardt et al. (2020) propose in their CE LD approach to set the F on 50; we applied this in the case of the circular kitchen. The value for N_{cycles} is determined by the number of use cycles for the material, represented by $C_{number,\ n}$ in Figure A1.1. This value should be found in the CE-LCI of the building material. Please note that VRPs indicate the start of a new use cycle, for example, re-use, remanufacturing, recycling, composting, or recovery; we do not consider the final disposal of a material as a use cycle.

Likewise, the percentage of initial production and construction impacts of a material allocated to its last use cycle (V_n) can be calculated using equation A1.3:

$$V_n = \frac{2}{N_{cycles} \cdot (F+1)} \cdot 100\% \tag{A1.3}$$

To determine the amount of the initial production and construction impacts allocated to intermediate use cycles, we first need to calculate the Δ_1 (shown in orange in Figure A1.1). Δ_1 expresses the decrease in percentage of impacts allocated between cycle 1 and cycle 2 (represented by $C_{number,1}$ and $C_{number,2}$, respectively, in Figure A1.1). The Δ_1 can be calculated using equation A1.4:

$$\Delta_1 = \frac{V_1 - V_n}{N_{cycles} - 1} \tag{A1.4}$$

in which we subtract V_n from V_1 and divide this by the number of cycles (N_{cycles}) minus 1 (i.e., the number of spaces between the cycles). These expressions are shown in blue in Figure A.1.1. The percentage of impact of initial production and construction allocated to use cycle 2 of a material can be calculated using equation A1.5:

$$\mathrm{V}_2 = \mathrm{V}_1 - \Delta_1 \tag{A1.5}$$

In which the Δ_1 is subtracted from the percentage of impact of initial production and construction allocated to use cycle 1 (V_1). Likewise, the impacts allocated to cycle 3 can be calculated by subtracting Δ_1 from V_2 and so on. Now that the percentage of impacts of initial production and construction allocated to each use cycle is determined (i.e., V_1 to V_n), the Af value for use in the CE-LCA can be selected. The Afcan be $V_1, V_2, V_{\dots}$ *to* V_n depending on the cycle number (C_{number}) in which the material is when applied in the assessed building component. So, for virgin material the Af is V_1. But for non-virgin material it could be values V_2 to V_n. Which cycle number the material is in should be found in the CE-LCI of the building component.

A.1.2.2. Determining the allocation fraction of disposal impacts for a material

To determine the $Af$of disposal impacts of each material (with different use cycles) applied in the building component, equations A1-A5 can be applied in a similar manner. Only, in this case V_1 refers to the impacts allocated to the last use cycle (i.e., where disposal occurs) and V_n refers to the first use cycle (i.e., cycle furthest from disposal).

A.1.2.3. Determining the allocation fraction of VRP impacts for a material

To determine the $Af$of VRP impacts of each material (with different use cycles) applied in the building component, the fraction of VRP impacts allocated to each use cycle of a material (V_{VRP}) should be calculated using equation A1.6:

$$V_{VRP} = \frac{1}{N_{cycles}} \tag{A1.6}$$

To support the ease of use of the CE LD approach in the CE-LCA model, we provided the allocation fractions for initial production and construction, VRPs, and disposal impacts for an F of 50 and N_{cycles} values between 1 and 10 in Table A1.1.

For more information on the background, development and evaluation of the CE LD allocation approach we refer to Eberhardt et al. (2020, pp. 9 & Supplementary material S3).

Appendix 2. Detailed CE-LCI of the kitchen variants

In this appendix we have provided the detailed CE-LCI of the kitchen variants.

Table A2.1
Detailed CE-LCI for the Business-As-Usual (BAU) kitchen

Design variant	Sub-components	Sub-sub components	Parts	Materials	Code in LCI flowchart	CE-LCA Life cycle stag	Description	Amount	Unit	Ecoinvent dataset*	Impact part of allocatio initial production & construction / VRPs / disposal
BAU kitchen	Lower kitchen cabinet		Panels	Particle board	$M_{1.1.1}$	A.1.1-A1.2	Particle board production	0.037	m3	particle board production, uncoated, average glue mix | particleboard, uncoated | APOS, S - RER	Initial production and construction
					$T_{1.1.1}$	A.3.2	Lorry from material supplier to panel coater	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.1.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	24.01*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.1.3}$	A.3.4	Lorry from kitchen manufacturer to user	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.1.4}$+$P_{1.1.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	24.01	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
				Melamine coating	$M_{1.2.1}$	A.1.1-A1.2	Coating with melamine paper	2.41	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
					$T_{1.2.1}$	A.3.2	Lorry from material supplier to panel coater	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.2.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	4.72*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.2.3}$	A.3.4	Lorry from kitchen manufacturer to user	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.2.4}$+$P_{1.2.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	4.72	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
			Back-panel	MDF	$M_{1.3.1}$	A.1.1-A1.2	MDF board production	0.0014	m3	medium density fibre board production, uncoated | medium density fibreboard | APOS, S - RER	Initial production and construction
					$T_{1.3.1}$	A.3.2	Lorry from material supplier to panel coater	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.3.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	0.9*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.3.3}$	A.3.4	Lorry from kitchen manufacturer to user	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.3.4}$+$P_{1.3.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.9	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
				Melamine coating	$M_{1.4.1}$	A.1.1-A1.2	Coating with melamine paper	0.23	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
					$T_{1.4.1}$	A.3.2	Lorry from material supplier to panel coater	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.4.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	0.45*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.4.3}$	A.3.4	Lorry from kitchen manufacturer to user	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.4.4}$+$P_{1.4.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.45	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
			Structural lath	Spruce	$M_{1.5.1}$	A.1.1-A1.2	Spruce lath production	0.52	kg	planing, lath, softwood, u=10% | sawnwood, lath, softwood, dried (u=10%), planed | APOS, S - CH	Initial production and construction
					$T_{1.5.1}$	A.3.2	Lorry from material supplier to kitchen manufacturer	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.5.2}$	A.3.4	Lorry from kitchen manufacturer to user	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.5.3}$+$P_{1.5.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.52	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
			Feet	Poly-propylene	$M_{1.6.1}$	A.1.1-A1.2	PP production	0.40	kg	polypropylene production, granulate | polypropylene, granulate | APOS, S - RER	Initial production and construction
					$T_{1.6.1}$	A.3.2	Lorry material supplier to part manufacturer	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$P_{1.6.1}$	A.3.2	Part production using injection moulding	0.40	kg	injection moulding | injection moulding | APOS, S - RER	Initial production and construction
					$T_{1.6.2}$	A.3.3	Lorry from part manufacturer to kitchen manufacturer	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.6.3}$	A.3.4	Lorry from kitchen manufacturer to user	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.6.4}$	C.5.7	Lorry from user to material recycler	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$P_{1.6.2}$	C.5.7	Recycling plastics	0.40	kg	polyethylene terephthalate production, granulate, amorphous, recycled | polyethylene terephthalate, granulate, amorphous, recycled | APOS, S - Europe without Switzerland	Value retention processes
					$T_{1.6.5}$	C.5.7	Lorry from material recycler to user	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{1.6.6}$+$P_{1.6.3}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.40	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
			Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{1.7.1}$	A.1.1-A1.2	Production hot rolled stainless steel	1.83	kg	steel production, chromium steel 18/8, hot rolled | steel, chromium steel 18/8, hot rolled | APOS, S - RER	Initial production and construction
					$T_{1.7.1}$	A.3.2	Container ship from material supplier to part manufacturer	1.83*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{1.7.2}$	A.3.2	Lorry material supplier to part manufacturer	1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.7.3}$	A.3.3	Lorry from part manufacturer to kitchen manufacturer	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.7.4}$	A.3.4	Lorry from kitchen manufacturer to user	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.7.5}$	C.5.7	(10 times) Lorry from user to material recycler	10*1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$P_{1.7.1}$ $T_{1.7.6}$	C.5.7	(10 times) Recycling metals + transport from recycler to user (in dataset)	10*1.83	kg	steel production, converter, unalloyed | steel, unalloyed | APOS, S - RER	Value retention processes
			Glue	PVAC	$M_{1.8.1}$	A.1.1-A1.2	PVAC production	0.10	kg	polyurethane production, flexible foam | polyurethane, flexible foam | APOS, S - RER	Initial production and construction
					$T_{1.8.1}$	A.3.2	Lorry material supplier to kitchen manufacturer	0.10*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.8.2}$	A.3.4	Lorry from kitchen manufacturer to user	0.10*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{1.8.3}$+$P_{1.8.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.10	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes

*For processes not available in the Ecoinvent Database, we selected the closest available process

Table A2.2
Detailed CE-LCI for the Reclaim! kitchen.

Design variant	Sub-components	Parts	Materials	Code in LCI flowchart	CE-LCA Life cycle stage	Description	Amount	Unit	Ecoinvent dataset*	Impact part of allocation: initial production & construction / VRPs / disposal
Reclaim! kitchen	Lower kitchen cabinet	Panels	Particle board	$M_{2.1.1}$	A.1.1	Particle board production	0.037	m3	particle board production, uncoated, average glue mix | particleboard, uncoated | APOS, S - RER	Initial production and construction
				$T_{2.1.1}$	A.1.2	Lorry from material supplier to panel coater	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.1.2}$	A.1.2	Lorry from panel coater to kitchen manufacturer	24.01*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.1.3}$	A.1.3	Lorry from kitchen manufacturer to user	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.1.4}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.1.5}$	A.3.4	Lorry from kitchen manufacturer to user	24.01*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.1.6}+P_{2.1.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	24.01	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
			Melamine coating	$M_{2.2.1}$	A.1.1	Coating with melamine paper	2.41	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
				$T_{2.2.1}$	A.1.2	Lorry from material supplier to panel coater	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.2.2}$	A.1.2	Lorry from panel coater to kitchen manufacturer	4.72*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.2.3}$	A.1.3	Lorry from kitchen manufacturer to user	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.2.4}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.2.5}$	A.3.4	Lorry from kitchen manufacturer to user	4.72*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.2.6}+P_{2.2.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	4.72	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Back-panel	MDF	$M_{2.3.1}$	A.1.1	MDF board production	0.0014	m3	medium density fibre board production, uncoated | medium density fibreboard | APOS, S - RER	Initial production and construction
				$T_{2.3.1}$	A.1.2	Lorry from material supplier to panel coater	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.3.2}$	A.1.2	Lorry from panel coater to kitchen manufacturer	0.9*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.3.3}$	A.1.3	Lorry from kitchen manufacturer to user	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.3.4}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.3.5}$	A.3.4	Lorry from kitchen manufacturer to user	0.9*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.3.6}+P_{2.3.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.9	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
			Melamine coating	$M_{2.4.1}$	A.1.1	Coating with melamine paper	0.23	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
				$T_{2.4.1}$	A.1.2	Lorry from material supplier to panel coater	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.4.2}$	A.1.2	Lorry from panel coater to kitchen manufacturer	0.45*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.4.3}$	A.1.3	Lorry from kitchen manufacturer to user	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.4.4}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.4.5}$	A.3.4	Lorry from kitchen manufacturer to user	0.45*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.4.6}+P_{2.4.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.45	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Structural lath	Spruce	$M_{2.5.1}$	A.1.1	Spruce lath production	0.52	kg	planing, lath, softwood, u=10% | sawnwood, lath, softwood, dried (u=10%), planed | APOS, S - CH	Initial production and construction
				$T_{2.5.1}$	A.1.2	Lorry from material supplier to kitchen manufacturer	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.5.2}$	A.1.3	Lorry from kitchen manufacturer to user	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.5.3}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.5.4}$	A.3.4	Lorry from kitchen manufacturer to user	0.52*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.5.5}+P_{2.5.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.52	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Feet	Poly-propylene	$M_{2.6.1}$	A.1.1	PP production	0.40	kg	polypropylene production, granulate | polypropylene, granulate | APOS, S - RER	Initial production and construction
				$T_{2.6.1}$	A.1.2	Lorry material supplier to part manufacturer	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$P_{1.6.1}$	A.1.2	Part production using injection moulding	0.40	kg	injection moulding | injection moulding | APOS, S - RER	Initial production and construction
				$T_{2.6.2}$	A.1.2	Lorry from part manufacturer to kitchen manufacturer	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.6.3}$	A.1.3	Lorry from kitchen manufacturer to user	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.6.4}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.6.5}$	A.3.4	Lorry from kitchen manufacturer to user	0.40*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.6.6}$	C.5.7	Lorry from user to material recycler	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$P_{2.6.2}$	C.5.7	Recycling plastics	0.40	kg	polyethylene terephthalate production, granulate, amorphous, recycled | polyethylene terephthalate, granulate, amorphous, recycled | APOS, S - Europe without Switzerland	Value retention processes
				$T_{2.6.7}$	C.5.7	Lorry from material recycler to user	0.40*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.6.8}+P_{2.6.3}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.40	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{2.7.1}$	A.1.1	Production hot rolled stainless steel	1.83	kg	steel production, chromium steel 18/8, hot rolled | steel, chromium steel 18/8, hot rolled | APOS, S - RER	Initial production and construction
				$T_{2.7.1}$	A.1.2	Container ship from material supplier to part manufacturer	1.83*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
				$T_{2.7.2}$	A.1.2	Lorry material supplier to part manufacturer	1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.7.3}$	A.1.2	Lorry from part manufacturer to kitchen manufacturer	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.7.4}$	A.1.3	Lorry from kitchen manufacturer to user	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.7.5}$	A.2.3	Lorry from user to kitchen manufacturer for re-use materials	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.7.6}$	A.3.4	Lorry from kitchen manufacturer to user	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.7.7}$	C.5.7	(10 times) Lorry from user to material recycler	10*1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
				$T_{2.7.8}+P_{2.7.1}$	C.5.7	(10 times) Recycling metals + transport from recycler to user (in dataset)	10*1.83	kg	steel production, converter, unalloyed | steel, unalloyed | APOS, S - RER	Value retention processes
		Glue	PVAC	$M_{2.8.1}$	A.1.1-A1.2	PVAC production	0.10	kg	polyurethane production, flexible foam | polyurethane, flexible foam | APOS, S - RER	Initial production and construction
				$T_{2.8.1}$	A.3.2	Lorry material supplier to kitchen manufacturer	0.10*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.8.2}$	A.3.4	Lorry from kitchen manufacturer to user	0.10*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
				$T_{2.8.3}+P_{1.8.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.10	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes

*For processes not available in the Ecoinvent Database, we selected the closest available process

Table A2.3
Detailed CE-LCI for the Plug-and-Play (P&P) kitchen.

Design variant	Sub-components	Sub-sub components	Parts	Materials	Code in LCI flowchart	CE-LCA Life cycle stage	Description	Amount	Unit	Ecoinvent dataset*	Impact part of allocation: initial production & construction / VRPs / disposal
P&P kitchen	Lower kitchen module	Construction	Frame & feet	Plywood	$M_{3.1.1.1}$	A.1.1-A1.2	Plywood production	0.011	m3	plywood production, for indoor use | plywood, for indoor use | APOS, S - RER	Initial production and construction
					$T_{3.1.1.1}$	A.3.2	Freight ship from material supplier to kitchen manufacturer	7.86*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.1.1.2}$	A.3.2	Lorry from material supplier to kitchen manufacturer	7.86*800	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.1.1.3}$	A.3.4	Lorry from kitchen manufacturer to user	7.86*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.1.1.4}$	C.2.6	Lorry from user to kitchen manufacturer	7.86*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.1.1.5}+P_{3.1.1.1}$	C.5.7	Transport kitchen manuf. to recycler (incl. in data) + chipping for OSB prod	7.86	kg	treatment of waste wood, post-consumer, sorting and shredding | wood chips, from post-consumer wood, measured as dry mass | APOS, S - CH	Value retention processes
					$T_{3.1.1.6}$	C.5.7	Lorry from OSB producer to user	7.86*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.1.1.7}+P_{3.1.1.2}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	7.86	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
			Feet extender	Stainless steel	$M_{3.1.2.1}$	A.1.1-A1.2	Production hot rolled stainless steel	0.13	kg	steel production, converter, chromium steel 18/8 | steel, chromium steel 18/8 | APOS, S - RER	Initial production and construction
					$T_{3.1.2.1}$	A.3.2	Container ship from material supplier to part manufacturer	0.13*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.1.2.2}$	A.3.2	Lorry material supplier to part manufacturer	0.13*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.1.2.3}$	A.3.3	Lorry from part manufacturer to kitchen manufacturer	0.13*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.1.2.4}$	A.3.4	Lorry from kitchen manufacturer to user	0.13*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.1.2.5}$	C.2.6	Lorry from user to kitchen manufacturer	0.13*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.1.2.6}$	C.5.7	(10 times) Lorry from kitchen manufacturer to material recycler	10*0.13*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.1.2.7}+P_{3.1.2.1}$	C.5.7	(10 times) Recycling metals + transport from recycler to user (in dataset)	10*0.13	kg	steel production, converter, unalloyed | steel, unalloyed | APOS, S - RER	Value retention processes
		Infill	Back and side panels (thin)	Triplex	$M_{3.2.1.1}$	A.1.1-A1.2	Triplex board production	0.003	m3	plywood production, for indoor use | plywood, for indoor use | APOS, S - RER	Initial production and construction
					$T_{3.2.1.1}$	A.3.2	Freight ship from material supplier to panel supplier	2.24*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.2.1.2}$	A.3.2	Lorry from material supplier to panel supplier	2.24*800	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.1.3}$	A.3.3	Lorry from panel supplier to kitchen manufacturer	2.24*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.1.4}$	A.3.4	Lorry from kitchen manufacturer to user	2.24*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.1.5}$	C.2.6	Lorry from user to kitchen manufacturer	2.24*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.1.6}+P_{3.2.1.1}$	C.5.7	Transport kitchen manuf. to recycler (included in dataset) + chipping for OS	9.68	kg	treatment of waste wood, post-consumer, sorting and shredding | wood chips, from post-consumer wood, measured as dry mass | APOS, S - CH	Value retention processes
					$T_{3.2.1.7}$	C.5.7	Lorry from OSB producer to user	9.68*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.1.8}+P_{3.2.1.2}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	2.24	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
			Bottom panel, shelve & drawer panels (thick)	Plywood	$M_{3.2.2.1}$	A.1.1-A1.2	Triplex board production	0.013	m3	plywood production, for indoor use | plywood, for indoor use | APOS, S - RER	Initial production and construction
					$T_{3.2.2.1}$	A.3.2	Freight ship from material supplier to panel coater	9.68*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.2.2.2}$	A.3.2	Lorry from material supplier to panel coater	9.68*800	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.2.3}$	A.3.3	Lorry from panel coater to kitchen manufacturer	9.68*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.2.4}$	A.3.4	Lorry from kitchen manufacturer to user	9.68*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.2.5}$	C.2.6	Lorry from user to kitchen manufacturer	9.68*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.2.6}$	C.4.4	Lorry from kitchen manufacturer to refurbisher	9.68*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.2.7}$	C.4.4	Lorry from refurbisher to user	9.68*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.2.8}+P_{3.2.2.1}$	C.5.7	Transport user to recycler (included in dataset) + chipping for OSB product	9.68	kg	treatment of waste wood, post-consumer, sorting and shredding | wood chips, from post-consumer wood, measured as dry mass | APOS, S - CH	Value retention processes
					$T_{3.2.2.9}$	C.5.7	Lorry from OSB producer to user	9.68*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.2.10}+P_{3.2.2.2}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	9.68	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
				HPL coating	$M_{3.2.3.1}$	A.1.1-A1.2	Coating with melamine paper	0.71	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
					$T_{3.2.3.1}$	A.3.2	Lorry from material supplier to panel coater	2.11*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.3.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	2.11*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.3.3}$	A.3.4	Lorry from kitchen manufacturer to user	2.11*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.2.3.4}$	C.2.6	Lorry from user to kitchen manufacturer	2.11*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.2.3.5}+P_{3.2.3.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	2.11	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Finishing	Fronts, side panels & plints	Plywood	$M_{3.3.1.1}$	A.1.1-A1.2	Triplex board production	0.016	m3	plywood production, for indoor use | plywood, for indoor use | APOS, S - RER	Initial production and construction
					$T_{3.3.1.1}$	A.3.2	Freight ship from material supplier to panel coater	12.1*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.3.1.2}$	A.3.2	Lorry from material supplier to panel coater	12.1*800	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.1.3}$	A.3.3	Lorry from panel coater to kitchen manufacturer	12.1*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.1.4}$	A.3.4	Lorry from kitchen manufacturer to user	12.1*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.1.5}$	C.2.6	Lorry from user to kitchen manufacturer	12.1*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.3.1.6}$	C.4.4	Lorry from kitchen manufacturer to refurbisher	12.1*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.3.1.7}$	C.4.4	Lorry from refurbisher to user	12.1*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.3.1.8}+P_{3.3.1.1}$	C.5.7	Transport user to recycler (included in dataset) + chipping for OSB product	12.1	kg	treatment of waste wood, post-consumer, sorting and shredding | wood chips, from post-consumer wood, measured as dry mass | APOS, S - CH	Value retention processes
					$T_{3.3.1.9}$	C.5.7	Lorry from OSB producer to user	12.1*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.3.1.10}+P_{3.3.1.2}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	12.1	kg	treatment of waste wood, untreated, municipal incineration | waste wood, untreated | APOS, S - CH	Value retention processes
				HPL coating	$M_{3.3.2.1}$	A.1.1-A1.2	Coating with melamine paper	1.03	m2	coating service, melamine impregnated paper, double-sided | coating, with melamine impregnated paper | APOS, S - RER	Initial production and construction
					$T_{3.3.2.1}$	A.3.2	Lorry from material supplier to panel coater	2.023*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.2.2}$	A.3.3	Lorry from panel coater to kitchen manufacturer	2.023*50	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.2.3}$	A.3.4	Lorry from kitchen manufacturer to user	2.023*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.3.2.4}$	C.2.6	Lorry from user to kitchen manufacturer	2.023*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.3.2.5}+P_{3.3.2.1}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	2.023	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes
		Connectors	Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{3.4.1.1}$	A.1.1-A1.2	Production hot rolled stainless steel	1.83	kg	steel production, chromium steel 18/8, hot rolled | steel, chromium steel 18/8, hot rolled | APOS, S - RER	Initial production and construction
					$T_{3.4.1.1}$	A.3.2	Container ship from material supplier to part manufacturer	1.83*2500	kg*km	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S - GLO	Initial production and construction
					$T_{3.4.1.2}$	A.3.2	Lorry material supplier to part manufacturer	1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.1.3}$	A.3.3	Lorry from part manufacturer to kitchen manufacturer	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.1.4}$	A.3.4	Lorry from kitchen manufacturer to user	1.83*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.1.5}$	C.2.6	Lorry from user to kitchen manufacturer	1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.4.1.6}$	C.5.7	(10 times) Lorry from kitchen manufacturer to material recycler	10*1.83*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.4.1.7}+P_{3.4.1.1}$	C.5.7	(10 times) Recycling metals + transport from recycler to user (in dataset)	10*1.83	kg	steel production, converter, unalloyed | steel, unalloyed | APOS, S - RER	Value retention processes
			Click connector	Poly-propylene	$M_{3.4.2.1}$	A.1.1-A1.2	PE production	0.064	kg	polyethylene production, low density, granulate | polyethylene, low density, granulate | APOS, S - RER	Initial production and construction
					$T_{3.4.2.1}$	A.3.2	Lorry material supplier to part manufacturer	0.064*400	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.2.2}$	A.3.3	Lorry from part manufacturer to kitchen manufacturer	0.064*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.2.3}$	A.3.4	Lorry from kitchen manufacturer to user	0.064*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Initial production and construction
					$T_{3.4.2.4}$	C.2.6	Lorry from user to kitchen manufacturer	0.064*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.4.2.5}$	C.5.7	(2 times) Lorry from kitchen manufacturer to part manufacturer	2*0.064*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$P_{3.4.2.1}$	C.5.7	(2 times) Closed loop recycling PE	2*0.064	kg	polyethylene terephthalate production, granulate, amorphous, recycled | polyethylene terephthalate, granulate, amorphous, recycled | APOS, S - Europe without Switzerland	Value retention processes
					$T_{3.4.2.6}$	C.5.7	(2 times) Lorry from part manufacturer to user	2*0.064*200	kg*km	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S - RER	Value retention processes
					$T_{3.4.2.7}+P_{3.4.2.2}$	C.6.2	Transport user to incineration plant + Incineration for energy recovery	0.064	kg	treatment of waste plastic, mixture, municipal incineration | waste plastic, mixture | APOS, S - Europe without Switzerland	Value retention processes

*For processes not available in the Ecoinvent Database, we selected the closest available process

Appendix 3. Detailed overview CE-LCIA parameters of kitchen variants

In this appendix we have provided the CE-LCIA parameters for the baseline and all sensitivity scenarios of the kitchen variants. For a further clarification on the sensitivity analysis scenarios, we refer to appendix 5.

Note that, in the P&P kitchen variant, when finishing and infill parts with re-use cycles are (re)placed, we assume virgin and re-used parts are alternated. As the C_{number} of the virgin and re-used parts vary, these parts have multiple sets of CE-LCIA parameters.

Table A3.1

Detailed CE-LCIA for the Business-As-Usual (BAU) kitchen

						Baseline						N_{cycles} | C+1						N_{cycles} | C+2						$L_{technical}$ - $L_{functional}$ | L7						$L_{technical}$ - $L_{functional}$ | L40						$L_{technical}$ - $L_{functional}$ | L80					
Design variant	Sub-components	Sub-sub components	Parts	Materials	Code in LCI flowchart	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{Initial\ production\ and\ construction,}$	$Af_{VRPs,1}$
BAU kitchen	**Lower kitchen cabinet**		**Panels**	**Particle board**	$M_{1.1.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.1.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.1.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.1.3}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.1.4}$+$P_{1.1.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%
				Melamine coating	$M_{1.2.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.2.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.2.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.2.3}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.2.4}$+$P_{1.2.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%
			Back-panel	**MDF**	$M_{1.3.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.3.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.3.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.3.3}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.3.4}$+$P_{1.3.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%
				Melamine coating	$M_{1.4.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.4.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.4.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.4.3}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.4.4}$+$P_{1.4.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%
			Structural lath	**Spruce**	$M_{1.5.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.5.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.5.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.5.3}$+$P_{1.5.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%
			Feet	**Poly-propylene**	$M_{1.6.1}$	1	3	1	80/20	65%		1	4	1	80/20	49%		1	5	1	80/20	39%		1	3	1	80/6,7	65%		1	3	1	80/40	65%		1	3	1	80/80	65%	
					$T_{1.6.1}$	1	3	1	80/20	65%		1	4	1	80/20	49%		1	5	1	80/20	39%		1	3	1	80/6,7	65%		1	3	1	80/40	65%		1	3	1	80/80	65%	
					$P_{1.6.1}$	1	3	1	80/20	65%		1	4	1	80/20	49%		1	5	1	80/20	39%		1	3	1	80/6,7	65%		1	3	1	80/40	65%		1	3	1	80/80	65%	
					$T_{1.6.2}$	1	3	1	80/20	65%		1	4	1	80/20	49%		1	5	1	80/20	39%		1	3	1	80/6,7	65%		1	3	1	80/40	65%		1	3	1	80/80	65%	
					$T_{1.6.3}$	1	3	1	80/20	65%		1	4	1	80/20	49%		1	5	1	80/20	39%		1	3	1	80/6,7	65%		1	3	1	80/40	65%		1	3	1	80/80	65%	
					$T_{1.6.4}$	1	3	1	80/20		33%	1	4	1	80/20		25%	1	5	1	80/20		20%	1	3	1	80/6,7		33%	1	3	1	80/40		33%	1	3	1	80/80		33%
					$P_{1.6.2}$	1	3	1	80/20		33%	1	4	1	80/20		25%	1	5	1	80/20		20%	1	3	1	80/6,7		33%	1	3	1	80/40		33%	1	3	1	80/80		33%
					$T_{1.6.5}$	1	3	1	80/20		33%	1	4	1	80/20		25%	1	5	1	80/20		20%	1	3	1	80/6,7		33%	1	3	1	80/40		33%	1	3	1	80/80		33%
					$T_{1.6.6}$+$P_{1.6.3}$	1	3	1	80/20		33%	1	4	1	80/20		25%	1	5	1	80/20		20%	1	3	1	80/6,7		33%	1	3	1	80/40		33%	1	3	1	80/80		33%
			Connectors (shelve carrier, hinges & drawer slides)	**Stainless steel**	$M_{1.7.1}$	1	11	1	80/20	18%		1	12	1	80/20	16%		1	13	1	80/20	15%		1	11	1	80/6,7	18%		1	11	1	80/40	18%		1	11	1	80/80	18%	
					$T_{1.7.1}$	1	11	1	80/20	18%		1	12	1	80/20	16%		1	13	1	80/20	15%		1	11	1	80/6,7	18%		1	11	1	80/40	18%		1	11	1	80/80	18%	
					$T_{1.7.2}$	1	11	1	80/20	18%		1	12	1	80/20	16%		1	13	1	80/20	15%		1	11	1	80/6,7	18%		1	11	1	80/40	18%		1	11	1	80/80	18%	
					$T_{1.7.3}$	1	11	1	80/20	18%		1	12	1	80/20	16%		1	13	1	80/20	15%		1	11	1	80/6,7	18%		1	11	1	80/40	18%		1	11	1	80/80	18%	
					$T_{1.7.4}$	1	11	1	80/20	18%		1	12	1	80/20	16%		1	13	1	80/20	15%		1	11	1	80/6,7	18%		1	11	1	80/40	18%		1	11	1	80/80	18%	
					$T_{1.7.5}$	1	11	1	80/20		9%	1	12	1	80/20		8%	1	13	1	80/20		8%	1	11	1	80/6,7		9%	1	11	1	80/40		9%	1	11	1	80/80		9%
					$P_{1.7.1}$ $T_{1.7.6}$	1	11	1	80/20		9%	1	12	1	80/20		8%	1	13	1	80/20		8%	1	11	1	80/6,7		9%	1	11	1	80/40		9%	1	11	1	80/80		9%
			Glue	**PVAC**	$M_{1.8.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.8.1}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.8.2}$	1	2	1	80/20	98%		1	3	1	80/20	65%		1	4	1	80/20	49%		1	2	1	80/6,7	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
					$T_{1.8.3}$+$P_{1.8.1}$	1	2	1	80/20		50%	1	3	1	80/20		33%	1	4	1	80/20		25%	1	2	1	80/6,7		50%	1	2	1	80/40		50%	1	2	1	80/80		50%

Table A3.2
Detailed CE-LCIA for the Reclaim! kitchen

					Baseline						N_{cycles} | C+1						N_{cycles} | C+2						$L_{technical}$ - $L_{functional}$ | L7						$L_{technical}$ - $L_{functional}$ | L20						$L_{technical}$ - $L_{functional}$ | L40						$L_{technical}$ - $L_{functional}$ | L80					
Design variant	Sub-components	Parts	Materials	Code in LCI flowchart	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$
Reclaim! kitchen	Lower kitchen cabinet	Panels	Particle board	$M_{2.1.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.1.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.1.2}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.1.3}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.1.4}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.1.5}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.1.6}+P_{2.1.1}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
			Melamine coating	$M_{2.2.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.2.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.2.2}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.2.3}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.2.4}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.2.5}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.2.6}+P_{2.2.1}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
		Back-panel	MDF	$M_{2.3.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.3.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.3.2}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.3.3}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.3.4}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.3.5}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.3.6}+P_{2.3.1}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
			Melamine coating	$M_{2.4.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.4.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.4.2}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.4.3}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.4.4}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.4.5}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.4.6}+P_{2.4.1}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
		Structural lath	Spruce	$M_{2.5.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.5.1}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.5.2}$	1	3	2	80/10	33%		1	4	2	80/10	33%		1	5	2	80/10	30%		1	3	2	80/6,7	33%		1	3	2	80/20	33%		1	3	2	80/40	33%		1	3	2	80/80	33%	
				$T_{2.5.3}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.5.4}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
				$T_{2.5.5}+P_{2.5.1}$	1	3	2	80/10		33%	1	4	2	80/10		25%	1	5	2	80/10		20%	1	3	2	80/6,7		33%	1	3	2	80/20		33%	1	3	2	80/40		33%	1	3	2	80/80		33%
		Feet	Poly-propylene	$M_{2.6.1}$	1	4	2	80/10	33%		1	5	2	80/10	30%		1	6	2	80/10	26%		1	4	2	80/6,7	33%		1	4	2	80/20	33%		1	4	2	80/40	33%		1	4	2	80/80	33%	
				$T_{2.6.1}$	1	4	2	80/10	33%		1	5	2	80/10	30%		1	6	2	80/10	26%		1	4	2	80/6,7	33%		1	4	2	80/20	33%		1	4	2	80/40	33%		1	4	2	80/80	33%	
				$P_{1.6.1}$	1	4	2	80/10	33%		1	5	2	80/10	30%		1	6	2	80/10	26%		1	4	2	80/6,7	33%		1	4	2	80/20	33%		1	4	2	80/40	33%		1	4	2	80/80	33%	
				$T_{2.6.2}$	1	4	2	80/10	33%		1	5	2	80/10	30%		1	6	2	80/10	26%		1	4	2	80/6,7	33%		1	4	2	80/20	33%		1	4	2	80/40	33%		1	4	2	80/80	33%	
				$T_{2.6.3}$	1	4	2	80/10	33%		1	5	2	80/10	30%		1	6	2	80/10	26%		1	4	2	80/6,7	33%		1	4	2	80/20	33%		1	4	2	80/40	33%		1	4	2	80/80	33%	
				$T_{2.6.4}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
				$T_{2.6.5}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
				$T_{2.6.6}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
				$P_{2.6.2}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
				$T_{2.6.7}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
				$T_{2.6.8}+P_{2.6.3}$	1	4	2	80/10		25%	1	5	2	80/10		20%	1	6	2	80/10		17%	1	4	2	80/6,7		25%	1	4	2	80/20		25%	1	4	2	80/40		25%	1	4	2	80/80		25%
		Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{2.7.1}$	1	12	2	80/10	15%		1	13	2	80/10	14%		1	14	2	80/10	13%		1	12	2	80/6,7	15%		1	12	2	80/20	15%		1	12	2	80/40	15%		1	12	2	80/80	15%	
				$T_{2.7.1}$	1	12	2	80/10	15%		1	13	2	80/10	14%		1	14	2	80/10	13%		1	12	2	80/6,7	15%		1	12	2	80/20	15%		1	12	2	80/40	15%		1	12	2	80/80	15%	
				$T_{2.7.2}$	1	12	2	80/10	15%		1	13	2	80/10	14%		1	14	2	80/10	13%		1	12	2	80/6,7	15%		1	12	2	80/20	15%		1	12	2	80/40	15%		1	12	2	80/80	15%	
				$T_{2.7.3}$	1	12	2	80/10	15%		1	13	2	80/10	14%		1	14	2	80/10	13%		1	12	2	80/6,7	15%		1	12	2	80/20	15%		1	12	2	80/40	15%		1	12	2	80/80	15%	
				$T_{2.7.4}$	1	12	2	80/10	15%		1	13	2	80/10	14%		1	14	2	80/10	13%		1	12	2	80/6,7	15%		1	12	2	80/20	15%		1	12	2	80/40	15%		1	12	2	80/80	15%	
				$T_{2.7.5}$	1	12	2	80/10		8%	1	13	2	80/10		8%	1	14	2	80/10		7%	1	12	2	80/6,7		8%	1	12	2	80/20		8%	1	12	2	80/40		8%	1	12	2	80/80		8%
				$T_{2.7.6}$	1	12	2	80/10		8%	1	13	2	80/10		8%	1	14	2	80/10		7%	1	12	2	80/6,7		8%	1	12	2	80/20		8%	1	12	2	80/40		8%	1	12	2	80/80		8%
				$T_{2.7.7}$	1	12	2	80/10		8%	1	13	2	80/10		8%	1	14	2	80/10		7%	1	12	2	80/6,7		8%	1	12	2	80/20		8%	1	12	2	80/40		8%	1	12	2	80/80		8%
				$T_{2.7.8}+P_{2.7.1}$	1	12	2	80/10		8%	1	13	2	80/10		8%	1	14	2	80/10		7%	1	12	2	80/6,7		8%	1	12	2	80/20		8%	1	12	2	80/40		8%	1	12	2	80/80		8%
		Glue	PVAC	$M_{2.8.1}$	1	2	1	80/10	98%		1	3	1	80/10	65%		1	4	1	80/10	49%		1	2	1	80/6,7	98%		1	2	1	80/20	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
				$T_{2.8.1}$	1	2	1	80/10	98%		1	3	1	80/10	65%		1	4	1	80/10	49%		1	2	1	80/6,7	98%		1	2	1	80/20	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
				$T_{2.8.2}$	1	2	1	80/10	98%		1	3	1	80/10	65%		1	4	1	80/10	49%		1	2	1	80/6,7	98%		1	2	1	80/20	98%		1	2	1	80/40	98%		1	2	1	80/80	98%	
				$T_{2.8.3}+P_{1.8.1}$	1	2	1	80/10		50%	1	3	1	80/10		33%	1	4	1	80/10		25%	1	2	1	80/6,7		50%	1	2	1	80/20		50%	1	2	1	80/40		50%	1	2	1	80/80		50%

(*continued on next page*)

Table A3.2 (*continued*)

						Baseline												N_{cycles} | C-3						N_{cycles} | C-2												N_{cycles} | C-1												N_{cycles} | C+1											
Design variant	Sub-components	Sub-sub components	Parts	Materials	Code in LCI flowchart	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{\text{initial production and construction},1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{\text{initial production and construction},2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{\text{initial production and construction},1}$	$Af_{VRPs,1}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{\text{initial production and construction},1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{\text{initial production and construction},2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{\text{initial production and construction},1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{\text{initial production and construction},2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{\text{initial production and construction},1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{\text{initial production and construction},2}$	$Af_{VRPs,2}$
P&P kitchen	Lower kitchen module	Construction	Frame & feet	Plywood	$M_{3.1.1.1}$	1	3	1	80/80	65%								1	2	1	80/80	98%		1	2	1	80/80	98%								1	2	1	80/80	98%								1	4	1	80/80	49%							
					$T_{3.1.1.1}$	1	3	1	80/80	65%								1	2	1	80/80	98%		1	2	1	80/80	98%								1	2	1	80/80	98%								1	4	1	80/80	49%							
					$T_{3.1.1.2}$	1	3	1	80/80	65%								1	2	1	80/80	98%		1	2	1	80/80	98%								1	2	1	80/80	98%								1	4	1	80/80	49%							
					$T_{3.1.1.3}$	1	3	1	80/80	65%								1	2	1	80/80	98%		1	2	1	80/80	98%								1	2	1	80/80	98%								1	4	1	80/80	49%							
					$T_{3.1.1.4}$	1	3	1	80/80		33%							1	2	1	80/80		50%	1	2	1	80/80		50%							1	2	1	80/80		50%							1	4	1	80/80		25%						
					$T_{3.1.1.5}+P_{3.1.1.1}$	1	3	1	80/80		33%																																											1	4	1	80/80		25%						
					$T_{3.1.1.6}$	1	3	1	80/80		33%																																											1	4	1	80/80		25%						
					$T_{3.1.1.7}+P_{3.1.1.2}$	1	3	1	80/80		33%							1	2	1	80/80		50%	1	2	1	80/80		50%							1	2	1	80/80		50%							1	4	1	80/80		25%						
			Feet extender	Stainless steel	$M_{3.1.2.1}$	1	11	1	80/80	18%								1	11	1	80/80	18%		1	11	1	80/80	18%								1	11	1	80/80	18%								1	12	1	80/80	16%							
					$T_{3.1.2.1}$	1	11	1	80/80	18%								1	11	1	80/80	18%		1	11	1	80/80	18%								1	11	1	80/80	18%								1	12	1	80/80	16%							
					$T_{3.1.2.2}$	1	11	1	80/80	18%								1	11	1	80/80	18%		1	11	1	80/80	18%								1	11	1	80/80	18%								1	12	1	80/80	16%							
					$T_{3.1.2.3}$	1	11	1	80/80	18%								1	11	1	80/80	18%		1	11	1	80/80	18%								1	11	1	80/80	18%								1	12	1	80/80	16%							
					$T_{3.1.2.4}$	1	11	1	80/80	18%								1	11	1	80/80	18%		1	11	1	80/80	18%								1	11	1	80/80	18%								1	12	1	80/80	16%							
					$T_{3.1.2.5}$	1	11	1	80/80		9%							1	11	1	80/80		9%	1	11	1	80/80		9%							1	11	1	80/80		9%							1	12	1	80/80		8%						
					$T_{3.1.2.6}$	1	11	1	80/80		9%							1	11	1	80/80		9%	1	11	1	80/80		9%							1	11	1	80/80		9%							1	12	1	80/80		8%						
					$T_{3.1.2.7}+P_{3.1.2.1}$	1	11	1	80/80		9%							1	11	1	80/80		9%	1	11	1	80/80		9%							1	11	1	80/80		9%							1	12	1	80/80		8%						
		Infill	Back and side panels (thin)	Triplex	$M_{3.2.1.1}$	1	3	1	80/20	65%								1	2	1	80/20	98%		1	2	1	80/20	98%								1	2	1	80/20	98%								1	4	1	80/20	49%							
					$T_{3.2.1.1}$	1	3	1	80/20	65%								1	2	1	80/20	98%		1	2	1	80/20	98%								1	2	1	80/20	98%								1	4	1	80/20	49%							
					$T_{3.2.1.2}$	1	3	1	80/20	65%								1	2	1	80/20	98%		1	2	1	80/20	98%								1	2	1	80/20	98%								1	4	1	80/20	49%							
					$T_{3.2.1.3}$	1	3	1	80/20	65%								1	2	1	80/20	98%		1	2	1	80/20	98%								1	2	1	80/20	98%								1	4	1	80/20	49%							
					$T_{3.2.1.4}$	1	3	1	80/20	65%								1	2	1	80/20	98%		1	2	1	80/20	98%								1	2	1	80/20	98%								1	4	1	80/20	49%							
					$T_{3.2.1.5}$	1	3	1	80/20		33%							1	2	1	80/20		50%	1	2	1	80/20		50%							1	2	1	80/20		50%							1	4	1	80/20		25%						
					$T_{3.2.1.6}+P_{3.2.1.1}$	1	3	1	80/20		33%																																											1	4	1	80/20		25%						
					$T_{3.2.1.7}$	1	3	1	80/20		33%																																											1	4	1	80/20		25%						
					$T_{3.2.1.8}+P_{3.2.1.2}$	1	3	1	80/20		33%							1	2	1	80/20		50%	1	2	1	80/20		50%							1	2	1	80/20		50%							1	4	1	80/20		25%						
			Bottom panel, shelve & drawer panels (thick)	Plywood	$M_{3.2.2.1}$	1	4	1	80/80	49%		1	4	2	80/80	33%		1	2	1	80/40	98%		1	2	1	80/40	98%								1	3	1	80/80	65%		1	3	2	80/80	33%		1	5	1	80/80	39%		1	5	2	80/80	30%	
					$T_{3.2.2.1}$	1	4	1	80/80	49%		1	4	2	80/80	33%		1	2	1	80/40	98%		1	2	1	80/40	98%								1	3	1	80/80	65%		1	3	2	80/80	33%		1	5	1	80/80	39%		1	5	2	80/80	30%	
					$T_{3.2.2.2}$	1	4	1	80/80	49%		1	4	2	80/80	33%		1	2	1	80/40	98%		1	2	1	80/40	98%								1	3	1	80/80	65%		1	3	2	80/80	33%		1	5	1	80/80	39%		1	5	2	80/80	30%	
					$T_{3.2.2.3}$	1	4	1	80/80	49%		1	4	2	80/80	33%		1	2	1	80/40	98%		1	2	1	80/40	98%								1	3	1	80/80	65%		1	3	2	80/80	33%		1	5	1	80/80	39%		1	5	2	80/80	30%	
					$T_{3.2.2.4}$	1	4	1	80/80	49%		1	4	2	80/80	33%		1	2	1	80/40	98%		1	2	1	80/40	98%								1	3	1	80/80	65%		1	3	2	80/80	33%		1	5	1	80/80	39%		1	5	2	80/80	30%	
					$T_{3.2.2.5}$	1	4	1	80/80		25%	1	4	2	80/80		25%	1	2	1	80/40		50%	1	2	1	80/40		50%							1	3	1	80/80		33%	1	3	2	80/80		33%	1	5	1	80/80		20%	1	5	2	80/80		20%
					$T_{3.2.2.6}$	1	4	1	80/80		25%	1	4	2	80/80		25%																			1	3	1	80/80		33%	1	3	2	80/80		33%	1	5	1	80/80		20%	1	5	2	80/80		20%
					$T_{3.2.2.7}$	1	4	1	80/80		25%	1	4	2	80/80		25%																			1	3	1	80/80		33%	1	3	2	80/80		33%	1	5	1	80/80		20%	1	5	2	80/80		20%
					$T_{3.2.2.8}+P_{3.2.2.1}$	1	4	1	80/80		25%	1	4	2	80/80		25%																															1	5	1	80/80		20%	1	5	2	80/80		20%
					$T_{3.2.2.9}$	1	4	1	80/80		25%	1	4	2	80/80		25%																															1	5	1	80/80		20%	1	5	2	80/80		20%
					$T_{3.2.2.10}+P_{3.2.2.2}$	1	4	1	80/80		25%	1	4	2	80/80		25%	1	2	1	80/40		50%	1	2	1	80/40		50%							1	3	1	80/80		33%	1	3	2	80/80		33%	1	5	1	80/80		20%	1	5	2	80/80		20%
				HPL coating	$M_{3.2.3.1}$	1	2	1	80/40	98%								1	2	1	80/40	98%		1	2	1	80/40	98%								1	2	1	80/40	98%								1	3	1	80/40	65%							
					$T_{3.2.3.1}$	1	2	1	80/40	98%								1	2	1	80/40	98%		1	2	1	80/40	98%								1	2	1	80/40	98%								1	3	1	80/40	65%							
					$T_{3.2.3.2}$	1	2	1	80/40	98%								1	2	1	80/40	98%		1	2	1	80/40	98%								1	2	1	80/40	98%								1	3	1	80/40	65%							
					$T_{3.2.3.3}$	1	2	1	80/40	98%								1	2	1	80/40	98%		1	2	1	80/40	98%								1	2	1	80/40	98%								1	3	1	80/40	65%							
					$T_{3.2.3.4}$	1	2	1	80/40		50%							1	2	1	80/40		50%	1	2	1	80/40		50%							1	2	1	80/40		50%							1	3	1	80/40		33%						
					$T_{3.2.3.5}+P_{3.2.3.1}$	1	2	1	80/40		50%							1	2	1	80/40		50%	1	2	1	80/40		50%							1	2	1	80/40		50%							1	3	1	80/40		33%						
		Finishing	Fronts, side panels & plints	Plywood	$M_{3.3.1.1}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	6	1	80/40	33%		1	6	2	80/40	26%	
					$T_{3.3.1.1}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	6	1	80/40	33%		1	6	2	80/40	26%	
					$T_{3.3.1.2}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	6	1	80/40	33%		1	6	2	80/40	26%	
					$T_{3.3.1.3}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	6	1	80/40	33%		1	6	2	80/40	26%	
					$T_{3.3.1.4}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	6	1	80/40	33%		1	6	2	80/40	26%	
					$T_{3.3.1.5}$	1	5	1	80/40		20%	1	5	2	80/40		20%	1	2	1	80/20		50%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	6	1	80/40		17%	1	6	2	80/40		17%
					$T_{3.3.1.6}$	1	5	1	80/40		20%	1	5	2	80/40		20%																			1	4	1	80/40		25%	1	4	2	80/40		25%	1	6	1	80/40		17%	1	6	2	80/40		17%
					$T_{3.3.1.7}$	1	5	1	80/40		20%	1	5	2	80/40		20%																			1	4	1	80/40		25%	1	4	2	80/40		25%	1	6	1	80/40		17%	1	6	2	80/40		17%
					$T_{3.3.1.8}+P_{3.3.1.1}$	1	5	1	80/40		20%	1	5	2	80/40		20%																															1	6	1	80/40		17%	1	6	2	80/40		17%
					$T_{3.3.1.9}$	1	5	1	80/40		20%	1	5	2	80/40		20%																															1	6	1	80/40		17%	1	6	2	80/40		17%
					$T_{3.3.1.10}+P_{3.3.1.2}$	1	5	1	80/40		20%	1	5	2	80/40		20%	1	2	1	80/20		50%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	6	1	80/40		17%	1	6	2	80/40		17%
				HPL coating	$M_{3.3.2.1}$	1	3	1	80/40	65%		1	3	2	80/40	33%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%	
					$T_{3.3.2.1}$	1	3	1	80/40	65%		1	3	2	80/40	33%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%	
					$T_{3.3.2.2}$	1	3	1	80/40	65%		1	3	2	80/40	33%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%	
					$T_{3.3.2.3}$	1	3	1	80/40	65%		1	3	2	80/40	33%		1	2	1	80/20	98%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	3	1	80/40	65%		1	3	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%	
					$T_{3.3.2.4}$	1	3	1	80/40		33%	1	3	2	80/40		33%	1	2	1	80/20		50%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	4	1	80/40		25%	1	4	2	80/40		25%
					$T_{3.3.2.5}+P_{3.3.2.1}$	1	3	1	80/40		33%	1	3	2	80/40		33%	1	2	1	80/20		50%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	3	1	80/40		33%	1	3	2	80/40		33%	1	4	1	80/40		25%	1	4	2	80/40		25%
		Connectors	Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{3.4.1.1}$	1	11	1	80/40	18%								1	11	1	80/40	18%		1	11	1	80/40	18%								1	11	1	80/40	18%								1	12	1	80/40	16%							
					$T_{3.4.1.1}$	1	11	1	80/40	18%								1	11	1	80/40	18%		1	11	1	80/40	18%								1	11	1	80/40	18%								1	12	1	80/40	16%							
					$T_{3.4.1.2}$	1	11	1	80/40	18%								1	11	1	80/40	18%		1	11	1	80/40	18%								1	11	1	80/40	18%								1	12	1	80/40	16%							
					$T_{3.4.1.3}$	1	11	1	80/40	18%								1	11	1	80/40	18%		1	11	1	80/40	18%								1	11	1	80/40	18%								1	12	1	80/40	16%							
					$T_{3.4.1.4}$	1	11	1	80/40	18%								1	11	1	80/40	18%		1	11	1	80/40	18%								1	11	1	80/40	18%								1	12	1	80/40	16%							
					$T_{3.4.1.5}$	1	11	1	80/40		9%							1	11	1	80/40		9%	1	11	1	80/40		9%							1	11	1	80/40		9%							1	12	1	80/40		8%						
					$T_{3.4.1.6}$	1	11	1	80/40		9%							1	11	1	80/40		9%	1	11	1	80/40		9%							1	11	1	80/40		9%							1	12	1	80/40		8%						
					$T_{3.4.1.7}+P_{3.4.1.1}$	1	11	1	80/40		9%							1	11	1	80/40		9%	1	11	1	80/40		9%							1	11	1	80/40		9%							1	12	1	80/40		8%						
			Click connector	Polypropylene	$M_{3.4.2.1}$	1	4	1	80/40	49%								1	4	1	80/40	49%		1	4	1	80/40	49%								1	4	1	80/40	49%								1	5	1	80/40	39%							
					$T_{3.4.2.1}$	1	4	1	80/40	49%								1	4	1	80/40	49%		1	4	1	80/40	49%								1	4	1	80/40	49%								1	5	1	80/40	39%							
					$T_{3.4.2.2}$	1	4	1	80/40	49%								1	4	1	80/40	49%		1	4	1	80/40	49%								1	4	1	80/40	49%								1	5	1	80/40	39%							
					$T_{3.4.2.3}$	1	4	1	80/40	49%								1	4	1	80/40	49%		1	4	1	80/40	49%								1	4	1	80/40	49%								1	5	1	80/40	39%							
					$T_{3.4.2.4}$	1	4	1	80/40		25%							1	4	1	80/40		25%	1	4	1	80/40		25%							1	4	1	80/40		25%							1	5	1	80/40		20%						
					$T_{3.4.2.5}$	1	4	1	80/40		25%							1	4	1	80/40		25%	1	4	1	80/40		25%							1	4	1	80/40		25%							1	5	1	80/40		20%						
					$P_{3.4.2.1}$	1	4	1	80/40		25%							1	4	1	80/40		25%	1	4	1	80/40		25%							1	4	1	80/40		25%							1	5	1	80/40		20%						
					$T_{3.4.2.6}$	1	4	1	80/40		25%							1	4	1	80/40		25%	1	4	1	80/40		25%							1	4	1	80/40		25%							1	5	1	80/40		20%						
					$T_{3.4.2.7}+P_{3.4.2.2}$	1	4	1	80/40		25%							1	4	1	80/40		25%	1	4	1	80/40		25%							1	4	1	80/40		25%							1	5	1	80/40		20%						

Table A3.3
Detailed CE-LCIA for the Plug-and-Play (P&P) kitchen

			N_{cycles} | C+2												$L_{functional}$ (finishing parts) | Lf=80-40-7-40, Lt=80-40-40-40																		$L_{functional}$ | Lf=80-40-40-40, Lt=80-40-40-40												$L_{technical}$ - $L_{functional}$ | Lt=7-7-7-7, Lf=7-7-3,5-7											
Parts	Materials	Code in LCI flowchart	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$	P_3	$N_{cycles,3}$	$C_{number,3}$	R_3	$Af_{initial\ production\ and\ construction,3}$	$Af_{VRPs,3}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$
rame & feet	Plywood	$M_{3.1.1.1}$	1	5	1	80/80	39%								1	3	1	80/80	65%														1	3	1	80/80	65%								1	3	1	80/6.7	65%							
		$T_{3.1.1.1}$	1	5	1	80/80	39%								1	3	1	80/80	65%														1	3	1	80/80	65%								1	3	1	80/6.7	65%							
		$T_{3.1.1.2}$	1	5	1	80/80	39%								1	3	1	80/80	65%														1	3	1	80/80	65%								1	3	1	80/6.7	65%							
		$T_{3.1.1.3}$	1	5	1	80/80	39%								1	3	1	80/80	65%														1	3	1	80/80	65%								1	3	1	80/6.7	65%							
		$T_{3.1.1.4}$	1	5	1	80/80		20%							1	3	1	80/80		33%													1	3	1	80/80		33%							1	3	1	80/6.7		33%						
		$T_{3.1.1.5}+P_{3.1.1.1}$	1	5	1	80/80		20%							1	3	1	80/80		33%													1	3	1	80/80		33%							1	3	1	80/6.7		33%						
		$T_{3.1.1.6}$	1	5	1	80/80		20%							1	3	1	80/80		33%													1	3	1	80/80		33%							1	3	1	80/6.7		33%						
		$T_{3.1.1.7}+P_{3.1.1.2}$	1	5	1	80/80		20%							1	3	1	80/80		33%													1	3	1	80/80		33%							1	3	1	80/6.7		33%						
eet extender	Stainless steel	$M_{3.1.2.1}$	1	13	1	80/80	15%								1	11	1	80/80	18%														1	11	1	80/80	18%								1	11	1	80/6.7	18%							
		$T_{3.1.2.1}$	1	13	1	80/80	15%								1	11	1	80/80	18%														1	11	1	80/80	18%								1	11	1	80/6.7	18%							
		$T_{3.1.2.2}$	1	13	1	80/80	15%								1	11	1	80/80	18%														1	11	1	80/80	18%								1	11	1	80/6.7	18%							
		$T_{3.1.2.3}$	1	13	1	80/80	15%								1	11	1	80/80	18%														1	11	1	80/80	18%								1	11	1	80/6.7	18%							
		$T_{3.1.2.4}$	1	13	1	80/80	15%								1	11	1	80/80	18%														1	11	1	80/80	18%								1	11	1	80/6.7	18%							
		$T_{3.1.2.5}$	1	13	1	80/80		8%							1	11	1	80/80		9%													1	11	1	80/80		9%							1	11	1	80/6.7		9%						
		$T_{3.1.2.6}$	1	13	1	80/80		8%							1	11	1	80/80		9%													1	11	1	80/80		9%							1	11	1	80/6.7		9%						
		$T_{3.1.2.7}+P_{3.1.2.1}$	1	13	1	80/80		8%							1	11	1	80/80		9%													1	11	1	80/80		9%							1	11	1	80/6.7		9%						
Back and side panels (thin)	Triplex	$M_{3.2.1.1}$	1	5	1	80/20	39%								1	3	1	80/20	65%														1	3	1	80/20	65%								1	3	1	80/6.7	65%							
		$T_{3.2.1.1}$	1	5	1	80/20	39%								1	3	1	80/20	65%														1	3	1	80/20	65%								1	3	1	80/6.7	65%							
		$T_{3.2.1.2}$	1	5	1	80/20	39%								1	3	1	80/20	65%														1	3	1	80/20	65%								1	3	1	80/6.7	65%							
		$T_{3.2.1.3}$	1	5	1	80/20	39%								1	3	1	80/20	65%														1	3	1	80/20	65%								1	3	1	80/6.7	65%							
		$T_{3.2.1.4}$	1	5	1	80/20	39%								1	3	1	80/20	65%														1	3	1	80/20	65%								1	3	1	80/6.7	65%							
		$T_{3.2.1.5}$	1	5	1	80/20		20%							1	3	1	80/20		33%													1	3	1	80/20		33%							1	3	1	80/6.7		33%						
		$T_{3.2.1.6}+P_{3.2.1.1}$	1	5	1	80/20		20%							1	3	1	80/20		33%													1	3	1	80/20		33%							1	3	1	80/6.7		33%						
		$T_{3.2.1.7}$	1	5	1	80/20		20%							1	3	1	80/20		33%													1	3	1	80/20		33%							1	3	1	80/6.7		33%						
		$T_{3.2.1.8}+P_{3.2.1.2}$	1	5	1	80/20		20%							1	3	1	80/20		33%													1	3	1	80/20		33%							1	3	1	80/6.7		33%						
ottom panel, shelve & drawer anels (thick)	Plywood	$M_{3.2.2.1}$	1	6	1	80/80	33%		1	6	2	80/80	26%		1	4	1	80/80	49%		1	4	2	80/80	33%								1	4	1	80/80	49%		1	4	2	80/80	33%		1	4	1	80/13.3	49%		1	4	2	80/13.3	33%	
		$T_{3.2.2.1}$	1	6	1	80/80	33%		1	6	2	80/80	26%		1	4	1	80/80	49%		1	4	2	80/80	33%								1	4	1	80/80	49%		1	4	2	80/80	33%		1	4	1	80/13.3	49%		1	4	2	80/13.3	33%	
		$T_{3.2.2.2}$	1	6	1	80/80	33%		1	6	2	80/80	26%		1	4	1	80/80	49%		1	4	2	80/80	33%								1	4	1	80/80	49%		1	4	2	80/80	33%		1	4	1	80/13.3	49%		1	4	2	80/13.3	33%	
		$T_{3.2.2.3}$	1	6	1	80/80	33%		1	6	2	80/80	26%		1	4	1	80/80	49%		1	4	2	80/80	33%								1	4	1	80/80	49%		1	4	2	80/80	33%		1	4	1	80/13.3	49%		1	4	2	80/13.3	33%	
		$T_{3.2.2.4}$	1	6	1	80/80	33%		1	6	2	80/80	26%		1	4	1	80/80	49%		1	4	2	80/80	33%								1	4	1	80/80	49%		1	4	2	80/80	33%		1	4	1	80/13.3	49%		1	4	2	80/13.3	33%	
		$T_{3.2.2.5}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
		$T_{3.2.2.6}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
		$T_{3.2.2.7}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
		$T_{3.2.2.8}+P_{3.2.2.1}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
		$T_{3.2.2.9}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
		$T_{3.2.2.10}+P_{3.2.2.2}$	1	6	1	80/80		17%	1	6	2	80/80		17%	1	4	1	80/80		25%	1	4	2	80/80		25%							1	4	1	80/80		25%	1	4	2	80/80		25%	1	4	1	80/13.3		25%	1	4	2	80/13.3		25%
	HPL coating	$M_{3.2.3.1}$	1	4	1	80/40	49%								1	2	1	80/40	98%														1	2	1	80/40	98%								1	2	1	80/6.7	98%							
		$T_{3.2.3.1}$	1	4	1	80/40	49%								1	2	1	80/40	98%														1	2	1	80/40	98%								1	2	1	80/6.7	98%							
		$T_{3.2.3.2}$	1	4	1	80/40	49%								1	2	1	80/40	98%														1	2	1	80/40	98%								1	2	1	80/6.7	98%							
		$T_{3.2.3.3}$	1	4	1	80/40	49%								1	2	1	80/40	98%														1	2	1	80/40	98%								1	2	1	80/6.7	98%							
		$T_{3.2.3.4}$	1	4	1	80/40		17%							1	2	1	80/40		50%													1	2	1	80/40		50%							1	2	1	80/6.7		50%						
		$T_{3.2.3.5}+P_{3.2.3.1}$	1	4	1	80/40		17%							1	2	1	80/40		50%													1	2	1	80/40		50%							1	2	1	80/6.7		50%						
ronts, side panels & plints	Plywood	$M_{3.3.1.1}$	1	7	1	80/40	28%		1	7	2	80/40	23%		1	8	1	80/20	25%		1	8	2	80/20	18%		1	8	2	80/20	11%		1	4	1	80/40	49%								1	5	1	80/6.7	39%		1	5	2	80/6.7	30%	
		$T_{3.3.1.1}$	1	7	1	80/40	28%		1	7	2	80/40	23%		1	8	1	80/20	25%		1	8	2	80/20	18%		1	8	2	80/20	11%		1	4	1	80/40	49%								1	5	1	80/6.7	39%		1	5	2	80/6.7	30%	
		$T_{3.3.1.2}$	1	7	1	80/40	28%		1	7	2	80/40	23%		1	8	1	80/20	25%		1	8	2	80/20	18%		1	8	2	80/20	11%		1	4	1	80/40	49%								1	5	1	80/6.7	39%		1	5	2	80/6.7	30%	
		$T_{3.3.1.3}$	1	7	1	80/40	28%		1	7	2	80/40	23%		1	8	1	80/20	25%		1	8	2	80/20	18%		1	8	2	80/20	11%		1	4	1	80/40	49%								1	5	1	80/6.7	39%		1	5	2	80/6.7	30%	
		$T_{3.3.1.4}$	1	7	1	80/40	28%		1	7	2	80/40	23%		1	8	1	80/20	25%		1	8	2	80/20	18%		1	8	2	80/20	11%		1	4	1	80/40	49%								1	5	1	80/6.7	39%		1	5	2	80/6.7	30%	
		$T_{3.3.1.5}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
		$T_{3.3.1.6}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
		$T_{3.3.1.7}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
		$T_{3.3.1.8}+P_{3.3.1.1}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
		$T_{3.3.1.9}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
		$T_{3.3.1.10}+P_{3.3.1.2}$	1	7	1	80/40		14%	1	7	2	80/40		14%	1	8	1	80/20		13%	1	8	2	80/20		13%	1	8	2	80/20		13%	1	4	1	80/40		25%							1	5	1	80/6.7		20%	1	5	2	80/6.7		20%
	HPL coating	$M_{3.3.2.1}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	6	1	80/20	33%		1	6	2	80/20	20%		1	6	2	80/20	7%		1	2	1	80/40	98%								1	3	1	80/6.7	65%		1	3	2	80/6.7	33%	
		$T_{3.3.2.1}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	6	1	80/20	33%		1	6	2	80/20	20%		1	6	2	80/20	7%		1	2	1	80/40	98%								1	3	1	80/6.7	65%		1	3	2	80/6.7	33%	
		$T_{3.3.2.2}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	6	1	80/20	33%		1	6	2	80/20	20%		1	6	2	80/20	7%		1	2	1	80/40	98%								1	3	1	80/6.7	65%		1	3	2	80/6.7	33%	
		$T_{3.3.2.3}$	1	5	1	80/40	39%		1	5	2	80/40	30%		1	6	1	80/20	33%		1	6	2	80/20	20%		1	6	2	80/20	7%		1	2	1	80/40	98%								1	3	1	80/6.7	65%		1	3	2	80/6.7	33%	
		$T_{3.3.2.4}$	1	5	1	80/40		20%	1	5	2	80/40		20%	1	6	1	80/20		17%	1	6	2	80/20		17%	1	6	2	80/20		17%	1	2	1	80/40		50%							1	3	1	80/6.7		33%	1	3	2	80/6.7		33%
		$T_{3.3.2.5}+P_{3.3.2.1}$	1	5	1	80/40		20%	1	5	2	80/40		20%	1	6	1	80/20		17%	1	6	2	80/20		17%	1	6	2	80/20		17%	1	2	1	80/40		50%							1	3	1	80/6.7		33%	1	3	2	80/6.7		33%
onnectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{3.4.1.1}$	1	13	1	80/40	15%								1	11	1	80/40	18%														1	11	1	80/40	18%								1	11	1	80/6.7	18%							
		$T_{3.4.1.1}$	1	13	1	80/40	15%								1	11	1	80/40	18%														1	11	1	80/40	18%								1	11	1	80/6.7	18%							
		$T_{3.4.1.2}$	1	13	1	80/40	15%								1	11	1	80/40	18%														1	11	1	80/40	18%								1	11	1	80/6.7	18%							
		$T_{3.4.1.3}$	1	13	1	80/40	15%								1	11	1	80/40	18%														1	11	1	80/40	18%								1	11	1	80/6.7	18%							
		$T_{3.4.1.4}$	1	13	1	80/40	15%								1	11	1	80/40	18%														1	11	1	80/40	18%								1	11	1	80/6.7	18%							
		$T_{3.4.1.5}$	1	13	1	80/40		8%							1	11	1	80/40		9%													1	11	1	80/40		9%							1	11	1	80/6.7		9%						
		$T_{3.4.1.6}$	1	13	1	80/40		8%							1	11	1	80/40		9%													1	11	1	80/40		9%							1	11	1	80/6.7		9%						
		$T_{3.4.1.7}+P_{3.4.1.1}$	1	13	1	80/40		8%							1	11	1	80/40		9%													1	11	1	80/40		9%							1	11	1	80/6.7		9%						
Click connector	Polypropylene	$M_{3.4.2.1}$	1	6	1	80/40	33%								1	4	1	80/40	49%														1	4	1	80/40	49%								1	4	1	80/6.7	49%							
		$T_{3.4.2.1}$	1	6	1	80/40	33%								1	4	1	80/40	49%														1	4	1	80/40	49%								1	4	1	80/6.7	49%							
		$T_{3.4.2.2}$	1	6	1	80/40	33%								1	4	1	80/40	49%														1	4	1	80/40	49%								1	4	1	80/6.7	49%							
		$T_{3.4.2.3}$	1	6	1	80/40	33%								1	4	1	80/40	49%														1	4	1	80/40	49%								1	4	1	80/6.7	49%							
		$T_{3.4.2.4}$	1	6	1	80/40		17%							1	4	1	80/40		25%													1	4	1	80/40		25%							1	4	1	80/6.7		25%						
		$T_{3.4.2.5}$	1	6	1	80/40		17%							1	4	1	80/40		25%													1	4	1	80/40		25%							1	4	1	80/6.7		25%						
		$P_{3.4.2.1}$	1	6	1	80/40		17%							1	4	1	80/40		25%													1	4	1	80/40		25%							1	4	1	80/6.7		25%						
		$T_{3.4.2.6}$	1	6	1	80/40		17%							1	4	1	80/40		25%													1	4	1	80/40		25%							1	4	1	80/6.7		25%						
		$T_{3.4.2.7}+P_{3.4.2.2}$	1	6	1	80/40		17%							1	4	1	80/40		25%													1	4	1	80/40		25%							1	4	1	80/6.7		25%						

(*continued on next page*)

Table A3.3 (*continued*)

			$L_{technical}$ - $L_{functional}$ | Lt=20-20-20-20, Lf=20-20-10-20												$L_{technical}$ - $L_{functional}$ | Lt=40-20-20-20, Lf=40-20-10-20												$L_{technical}$ - $L_{functional}$ | Lt=80-80-80-80, Lf=80-80-40-80											
Parts	Materials	Code in LCI flowchart	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$	P_1	$N_{cycles,1}$	$C_{number,1}$	R_1	$Af_{initial\ production\ and\ construction,1}$	$Af_{VRPs,1}$	P_2	$N_{cycles,2}$	$C_{number,2}$	R_2	$Af_{initial\ production\ and\ construction,2}$	$Af_{VRPs,2}$
rame & feet	Plywood	$M_{3.1.1.1}$	1	3	1	80/20	65%								1	3	1	80/40	65%								1	3	1	80/80	65%							
		$T_{3.1.1.1}$	1	3	1	80/20	65%								1	3	1	80/40	65%								1	3	1	80/80	65%							
		$T_{3.1.1.2}$	1	3	1	80/20	65%								1	3	1	80/40	65%								1	3	1	80/80	65%							
		$T_{3.1.1.3}$	1	3	1	80/20	65%								1	3	1	80/40	65%								1	3	1	80/80	65%							
		$T_{3.1.1.4}$	1	3	1	80/20		33%							1	3	1	80/40		33%							1	3	1	80/80		33%						
		$T_{3.1.1.5}+P_{3.1.1.1}$	1	3	1	80/20		33%							1	3	1	80/40		33%							1	3	1	80/80		33%						
		$T_{3.1.1.6}$	1	3	1	80/20		33%							1	3	1	80/40		33%							1	3	1	80/80		33%						
		$T_{3.1.1.7}+P_{3.1.1.2}$	1	3	1	80/20		33%							1	3	1	80/40		33%							1	3	1	80/80		33%						
eet extender	Stainless steel	$M_{3.1.2.1}$	1	11	1	80/20	18%								1	11	1	80/40	18%								1	11	1	80/80	18%							
		$T_{3.1.2.1}$	1	11	1	80/20	18%								1	11	1	80/40	18%								1	11	1	80/80	18%							
		$T_{3.1.2.2}$	1	11	1	80/20	18%								1	11	1	80/40	18%								1	11	1	80/80	18%							
		$T_{3.1.2.3}$	1	11	1	80/20	18%								1	11	1	80/40	18%								1	11	1	80/80	18%							
		$T_{3.1.2.4}$	1	11	1	80/20	18%								1	11	1	80/40	18%								1	11	1	80/80	18%							
		$T_{3.1.2.5}$	1	11	1	80/20		9%							1	11	1	80/40		9%							1	11	1	80/80		9%						
		$T_{3.1.2.6}$	1	11	1	80/20		9%							1	11	1	80/40		9%							1	11	1	80/80		9%						
		$T_{3.1.2.7}+P_{3.1.2.1}$	1	11	1	80/20		9%							1	11	1	80/40		9%							1	11	1	80/80		9%						
Back and side panels (thin)	Triplex	$M_{3.2.1.1}$	1	3	1	80/20	65%								1	3	1	80/10	65%								1	3	1	80/80	65%							
		$T_{3.2.1.1}$	1	3	1	80/20	65%								1	3	1	80/10	65%								1	3	1	80/80	65%							
		$T_{3.2.1.2}$	1	3	1	80/20	65%								1	3	1	80/10	65%								1	3	1	80/80	65%							
		$T_{3.2.1.3}$	1	3	1	80/20	65%								1	3	1	80/10	65%								1	3	1	80/80	65%							
		$T_{3.2.1.4}$	1	3	1	80/20	65%								1	3	1	80/10	65%								1	3	1	80/80	65%							
		$T_{3.2.1.5}$	1	3	1	80/20		33%							1	3	1	80/10		33%							1	3	1	80/80		33%						
		$T_{3.2.1.6}+P_{3.2.1.1}$	1	3	1	80/20		33%							1	3	1	80/10		33%							1	3	1	80/80		33%						
		$T_{3.2.1.7}$	1	3	1	80/20		33%							1	3	1	80/10		33%							1	3	1	80/80		33%						
		$T_{3.2.1.8}+P_{3.2.1.2}$	1	3	1	80/20		33%							1	3	1	80/10		33%							1	3	1	80/80		33%						
ottom panel, shelve & drawer anels (thick)	Plywood	$M_{3.2.2.1}$	1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/80	49%							
		$T_{3.2.2.1}$	1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/80	49%							
		$T_{3.2.2.2}$	1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/80	49%							
		$T_{3.2.2.3}$	1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/80	49%							
		$T_{3.2.2.4}$	1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/40	49%		1	4	2	80/40	33%		1	4	1	80/80	49%							
		$T_{3.2.2.5}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
		$T_{3.2.2.6}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
		$T_{3.2.2.7}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
		$T_{3.2.2.8}+P_{3.2.2.1}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
		$T_{3.2.2.9}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
		$T_{3.2.2.10}+P_{3.2.2.2}$	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/40		25%	1	4	2	80/40		25%	1	4	1	80/80		25%						
	HPL coating	$M_{3.2.3.1}$	1	2	1	80/20	98%								1	2	1	80/20	98%								1	2	1	80/80	98%							
		$T_{3.2.3.1}$	1	2	1	80/20	98%								1	2	1	80/20	98%								1	2	1	80/80	98%							
		$T_{3.2.3.2}$	1	2	1	80/20	98%								1	2	1	80/20	98%								1	2	1	80/80	98%							
		$T_{3.2.3.3}$	1	2	1	80/20	98%								1	2	1	80/20	98%								1	2	1	80/80	98%							
		$T_{3.2.3.4}$	1	2	1	80/20		50%							1	2	1	80/20		50%							1	2	1	80/80		50%						
		$T_{3.2.3.5}+P_{3.2.3.1}$	1	2	1	80/20		50%							1	2	1	80/20		50%							1	2	1	80/80		50%						
Fronts, side panels & plints	Plywood	$M_{3.3.1.1}$	1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/80	39%		1	5	2	80/80	30%	
		$T_{3.3.1.1}$	1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/80	39%		1	5	2	80/80	30%	
		$T_{3.3.1.2}$	1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/80	39%		1	5	2	80/80	30%	
		$T_{3.3.1.3}$	1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/80	39%		1	5	2	80/80	30%	
		$T_{3.3.1.4}$	1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/20	39%		1	5	2	80/20	30%		1	5	1	80/80	39%		1	5	2	80/80	30%	
		$T_{3.3.1.5}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
		$T_{3.3.1.6}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
		$T_{3.3.1.7}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
		$T_{3.3.1.8}+P_{3.3.1.1}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
		$T_{3.3.1.9}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
		$T_{3.3.1.10}+P_{3.3.1.2}$	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/20		20%	1	5	2	80/20		20%	1	5	1	80/80		20%	1	5	2	80/80		20%
	HPL coating	$M_{3.3.2.1}$	1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/80	65%		1	3	2	80/80	33%	
		$T_{3.3.2.1}$	1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/80	65%		1	3	2	80/80	33%	
		$T_{3.3.2.2}$	1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/80	65%		1	3	2	80/80	33%	
		$T_{3.3.2.3}$	1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/20	65%		1	3	2	80/20	33%		1	3	1	80/80	65%		1	3	2	80/80	33%	
		$T_{3.3.2.4}$	1	3	1	80/20		33%	1	3	2	80/20		33%	1	3	1	80/20		33%	1	3	2	80/20		33%	1	3	1	80/80		33%	1	3	2	80/80		33%
		$T_{3.3.2.5}+P_{3.3.2.1}$	1	3	1	80/20		33%	1	3	2	80/20		33%	1	3	1	80/20		33%	1	3	2	80/20		33%	1	3	1	80/80		33%	1	3	2	80/80		33%
Connectors (shelve carrier, hinges & drawer slides)	Stainless steel	$M_{3.4.1.1}$	1	11	1	80/20	18%								1	11	1	80/20	18%								1	11	1	80/80	18%							
		$T_{3.4.1.1}$	1	11	1	80/20	18%								1	11	1	80/20	18%								1	11	1	80/80	18%							
		$T_{3.4.1.2}$	1	11	1	80/20	18%								1	11	1	80/20	18%								1	11	1	80/80	18%							
		$T_{3.4.1.3}$	1	11	1	80/20	18%								1	11	1	80/20	18%								1	11	1	80/80	18%							
		$T_{3.4.1.4}$	1	11	1	80/20	18%								1	11	1	80/20	18%								1	11	1	80/80	18%							
		$T_{3.4.1.5}$	1	11	1	80/20		9%							1	11	1	80/20		9%							1	11	1	80/80		9%						
		$T_{3.4.1.6}$	1	11	1	80/20		9%							1	11	1	80/20		9%							1	11	1	80/80		9%						
		$T_{3.4.1.7}+P_{3.4.1.1}$	1	11	1	80/20		9%							1	11	1	80/20		9%							1	11	1	80/80		9%						
Click connector	Poly-propylene	$M_{3.4.2.1}$	1	4	1	80/20	49%								1	4	1	80/20	49%								1	4	1	80/80	49%							
		$T_{3.4.2.1}$	1	4	1	80/20	49%								1	4	1	80/20	49%								1	4	1	80/80	49%							
		$T_{3.4.2.2}$	1	4	1	80/20	49%								1	4	1	80/20	49%								1	4	1	80/80	49%							
		$T_{3.4.2.3}$	1	4	1	80/20	49%								1	4	1	80/20	49%								1	4	1	80/80	49%							
		$T_{3.4.2.4}$	1	4	1	80/20		25%							1	4	1	80/20		25%							1	4	1	80/80		25%						
		$T_{3.4.2.5}$	1	4	1	80/20		25%							1	4	1	80/20		25%							1	4	1	80/80		25%						
		$P_{3.4.2.1}$	1	4	1	80/20		25%							1	4	1	80/20		25%							1	4	1	80/80		25%						
		$T_{3.4.2.6}$	1	4	1	80/20		25%							1	4	1	80/20		25%							1	4	1	80/80		25%						
		$T_{3.4.2.7}+P_{3.4.2.2}$	1	4	1	80/20		25%							1	4	1	80/20		25%							1	4	1	80/80		25%						

Note that, in the P&P kitchen variant, when finishing and infill parts with re-use cycles are (re)placed, we assume virgin and re-used parts are alternated. As the Cnumber of the virgin and re-used parts vary, these parts have multiple sets of CE-LCIA parameters.

Appendix 4. Analysis of the CE-LCIA results

This appendix includes a deeper analysis of the CE-LCIA results of the BAU, Reclaim! and P&P kitchen variants.

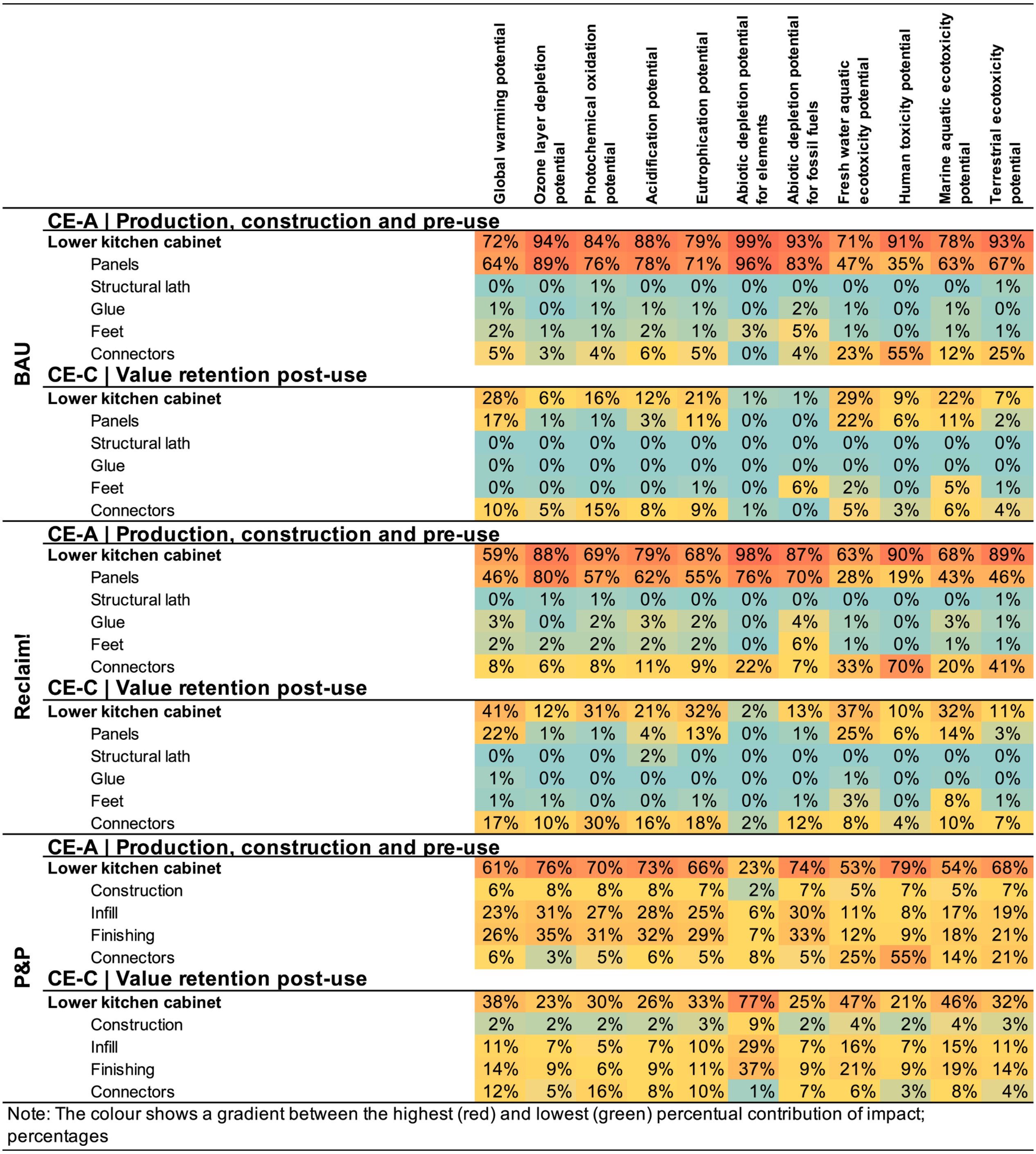
A4.1. Impact distribution between 'production, construction and pre-use' and 'value retention post-use' for the lower kitchen cabinet and its subcomponents

Table A4.1 shows the impact distribution between modules CE-A (i.e., production, construction and pre-use) and CE-C (i.e., value retention post-use) for the lower kitchen cabinet and its subcomponents per impact category in percentage.

Which life cycle stages contribute most to the results varies per design variant and impact category. In the BAU kitchen the materials have a low number of use cycles; a higher share of impacts originates from production, construction and pre-use, namely between 71%–99%. In the Reclaim! kitchen, materials have one more use cycle than in the BAU kitchen: between 59%–98% of impacts originate from production, construction and pre-

Table A4.1

Contribution of impacts for modules CE-A and CE-C for the lower kitchen cabinet and subcomponents



		Global warming potential	Ozone layer depletion potential	Photochemical oxidation potential	Acidification potential	Eutrophication potential	Abiotic depletion potential for elements	Abiotic depletion potential for fossil fuels	Fresh water aquatic ecotoxicity potential	Human toxicity potential	Marine aquatic ecotoxicity potential	Terrestrial ecotoxicity potential
BAU	**CE-A | Production, construction and pre-use**											
	Lower kitchen cabinet	72%	94%	84%	88%	79%	99%	93%	71%	91%	78%	93%
	Panels	64%	89%	76%	78%	71%	96%	83%	47%	35%	63%	67%
	Structural lath	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	1%
	Glue	1%	0%	1%	1%	1%	0%	2%	1%	0%	1%	0%
	Feet	2%	1%	1%	2%	1%	3%	5%	1%	0%	1%	1%
	Connectors	5%	3%	4%	6%	5%	0%	4%	23%	55%	12%	25%
	CE-C | Value retention post-use											
	Lower kitchen cabinet	28%	6%	16%	12%	21%	1%	1%	29%	9%	22%	7%
	Panels	17%	1%	1%	3%	11%	0%	0%	22%	6%	11%	2%
	Structural lath	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Glue	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Feet	0%	0%	0%	0%	1%	0%	6%	2%	0%	5%	1%
	Connectors	10%	5%	15%	8%	9%	1%	0%	5%	3%	6%	4%
Reclaim!	**CE-A | Production, construction and pre-use**											
	Lower kitchen cabinet	59%	88%	69%	79%	68%	98%	87%	63%	90%	68%	89%
	Panels	46%	80%	57%	62%	55%	76%	70%	28%	19%	43%	46%
	Structural lath	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	1%
	Glue	3%	0%	2%	3%	2%	0%	4%	1%	0%	3%	1%
	Feet	2%	2%	2%	2%	2%	0%	6%	1%	0%	1%	1%
	Connectors	8%	6%	8%	11%	9%	22%	7%	33%	70%	20%	41%
	CE-C | Value retention post-use											
	Lower kitchen cabinet	41%	12%	31%	21%	32%	2%	13%	37%	10%	32%	11%
	Panels	22%	1%	1%	4%	13%	0%	1%	25%	6%	14%	3%
	Structural lath	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%
	Glue	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
	Feet	1%	1%	0%	0%	1%	0%	1%	3%	0%	8%	1%
	Connectors	17%	10%	30%	16%	18%	2%	12%	8%	4%	10%	7%
P&P	**CE-A | Production, construction and pre-use**											
	Lower kitchen cabinet	61%	76%	70%	73%	66%	23%	74%	53%	79%	54%	68%
	Construction	6%	8%	8%	8%	7%	2%	7%	5%	7%	5%	7%
	Infill	23%	31%	27%	28%	25%	6%	30%	11%	8%	17%	19%
	Finishing	26%	35%	31%	32%	29%	7%	33%	12%	9%	18%	21%
	Connectors	6%	3%	5%	6%	5%	8%	5%	25%	55%	14%	21%
	CE-C | Value retention post-use											
	Lower kitchen cabinet	38%	23%	30%	26%	33%	77%	25%	47%	21%	46%	32%
	Construction	2%	2%	2%	2%	3%	9%	2%	4%	2%	4%	3%
	Infill	11%	7%	5%	7%	10%	29%	7%	16%	7%	15%	11%
	Finishing	14%	9%	6%	9%	11%	37%	9%	21%	9%	19%	14%
	Connectors	12%	5%	16%	8%	10%	1%	7%	6%	3%	8%	4%

Note: The colour shows a gradient between the highest (red) and lowest (green) percentual contribution of impact; percentages use. Introducing multiple use cycles results in higher shares of impact originating from 'value retention post-use': in the P&P kitchen, only 53–79% of impacts originate from production, construction and pre-use. An exception is the 'abiotic depletion for elements' category, where only 23% are production, construction and pre-use impacts. This is due to the high abiotic depletion potential of 'wood chipping for OSB production' during recycling of wooden parts. The effect of including multiple cycles is also visible in the stainless-steel connectors: the assumed 10 recycling cycles for virgin stainless steel result in an Af of 0.18 for initial production and construction impacts and an Af of 0.09 for impacts of each recycling cycle. As such the share of impacts of value retention post-use is larger than the share of impacts of production, construction and pre-use: double or triple for the first five impact categories. However, the distribution of impacts also greatly depends on impacts emanating from production versus recycling processes. For example, in the toxicity categories, the impacts from initial production and construction of stainless steel still contribute the majority share.

Which materials or processes contribute most to the results varies per impact category. From the CE-LCI, we see that the panels form the bulk of the material in the BAU and Reclaim! kitchens and the infill and finishing parts in the P&P kitchen. Their initial production and construction contribute significantly in nearly all impact categories; in the P&P kitchen the recycling process 'chipping for OSB production' results in high share of impacts, especially in the abiotic depletion for elements category. However, considering the limited mass of the stainless steel and coatings (i.e., melamine), we found that these materials contribute significantly to the total impacts, especially for the toxicity categories. When normalising the results (see also appendix 6, Table A6.3), we found these are most significant. Finally, most of the impact originates from material production and VRPs; transport played a limited role.

A4.2. Impact allocation over the RSP

To illustrate how impacts are allocated to the kitchen over the RSP we plotted the (allocated) GWP over time in Figure A4.1. The y-axis shows the years within the RSP when impact is allocated to the kitchen. For the BAU and Reclaim! variants, impacts are allocated to the kitchen when the entire kitchen cabinet is placed and replaced every 20 or 10 years, respectively. For the P&P kitchen the largest shares of impact are allocated at initial placement ($t = 0$), and the replacement of the finishing, infill and connectors ($t = 40$). The replacement of the finishing and part of the infill at $t = 20$ and $t = 60$ result in a modest increase in allocated impact, showing the benefit of facilitating partial replacements.

This graph shows tipping points for the GWP: prior to $t = 7$, the Reclaim! variant has the lowest allocated GWP compared to the other variants. When $t>7$ years, the P&P variant continues to have the lowest (allocated) GWP. If a similar analysis is done for other impact categories, the y-values on which impacts are allocated to the kitchen would remain the same. However, how much impact is allocated per (re)placement might differ per impact category – changing the tipping points.

A4.3. Impact between use cycles of materials applied in the kitchen in relation to the RSP

The above mentioned results merely show the impacts of the circular system allocated to the kitchen. Neither Table A4.1 nor Figure A4.1 provides insight into the distribution of impacts between the use cycle in the kitchen and the use cycles happening 'outside' of the assessed kitchen. Reporting the impacts allocated 'inside' and 'outside' of the use cycle of the assessed kitchen does not necessarily lead to more transparency. First, impacts which have already occurred in the use cycle of the kitchen are allocated to cycles occurring 'outside' of the assessed kitchen. Likewise, some of the impacts of cycles which are yet to occur have already been allocated to the use cycle of the kitchen. Second, depending on which materials are applied, impacts 'outside' of the assessed kitchen could compile impacts of multiple use cycles. For metals used in the kitchen, impacts outside the use cycle of the kitchen include impacts of 10 recycling cycles. Whilst for particle boards in the BAU variant, it only includes impacts of one use cycle (e.g., recovery of particle board for energy). To increase the transparency of multi-cycling LCAs, the impacts could be reported per use cycle – per material.

Figures A4.2a-c report the distribution of impacts between use cycles of materials applied in the kitchen variants plotted over the RSP. It shows the cohesion between the parameters N_{cycles}, C_{number}, R – and the resulting A_f values per use cycle. Showing the impact distribution could increase transparency and comparability between CE-LCAs; it could support deeper analysis of the CE-LCIA results. However, reporting impacts per cycle could also (further) complexify CE-LCA. Interpretation of impacts reported per cycle might be feasible and insightful for building materials or simple building components. Yet, for more complex composites – as is the case in the kitchens – it results in extensive CE-LCIA datasets. We question if this supports decision-making: comparing environmental impact performance of sets of individual cycles between kitchen variants is more a comparison of circular systems than a comparison of circular building components (in a circular system).

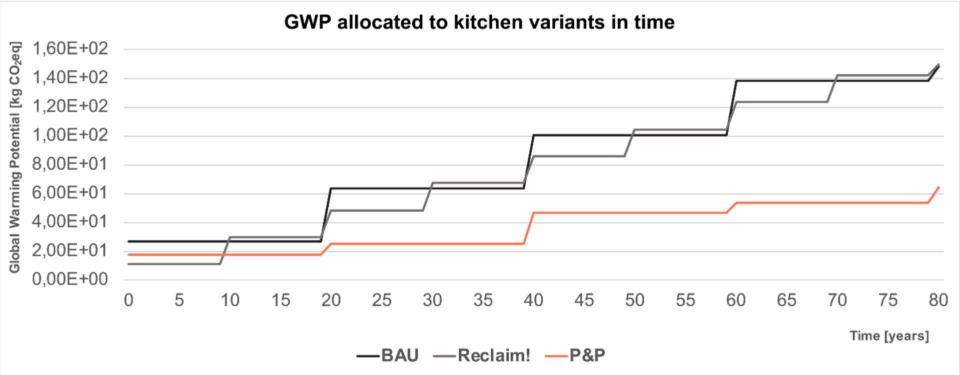


Fig. A4.1. Global Warming Potential allocated to kitchen variants over 80 years.

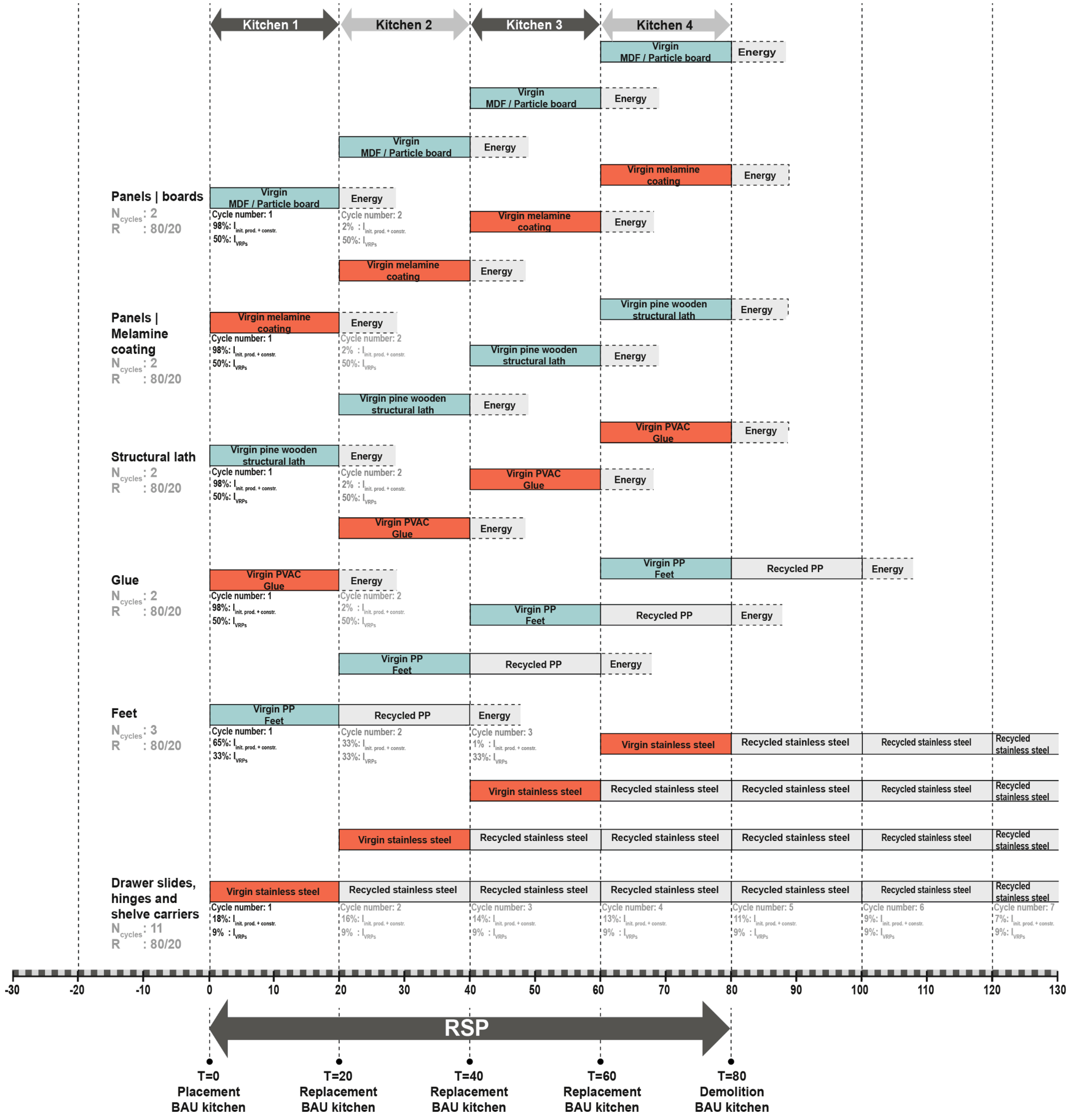


Fig. A4.2a. Distribution of impacts between use cycles of materials applied in the BAU kitchen in relation to the RSP. (the green and red colour highlight the use cycles when the material is applied in the assessed kitchen).

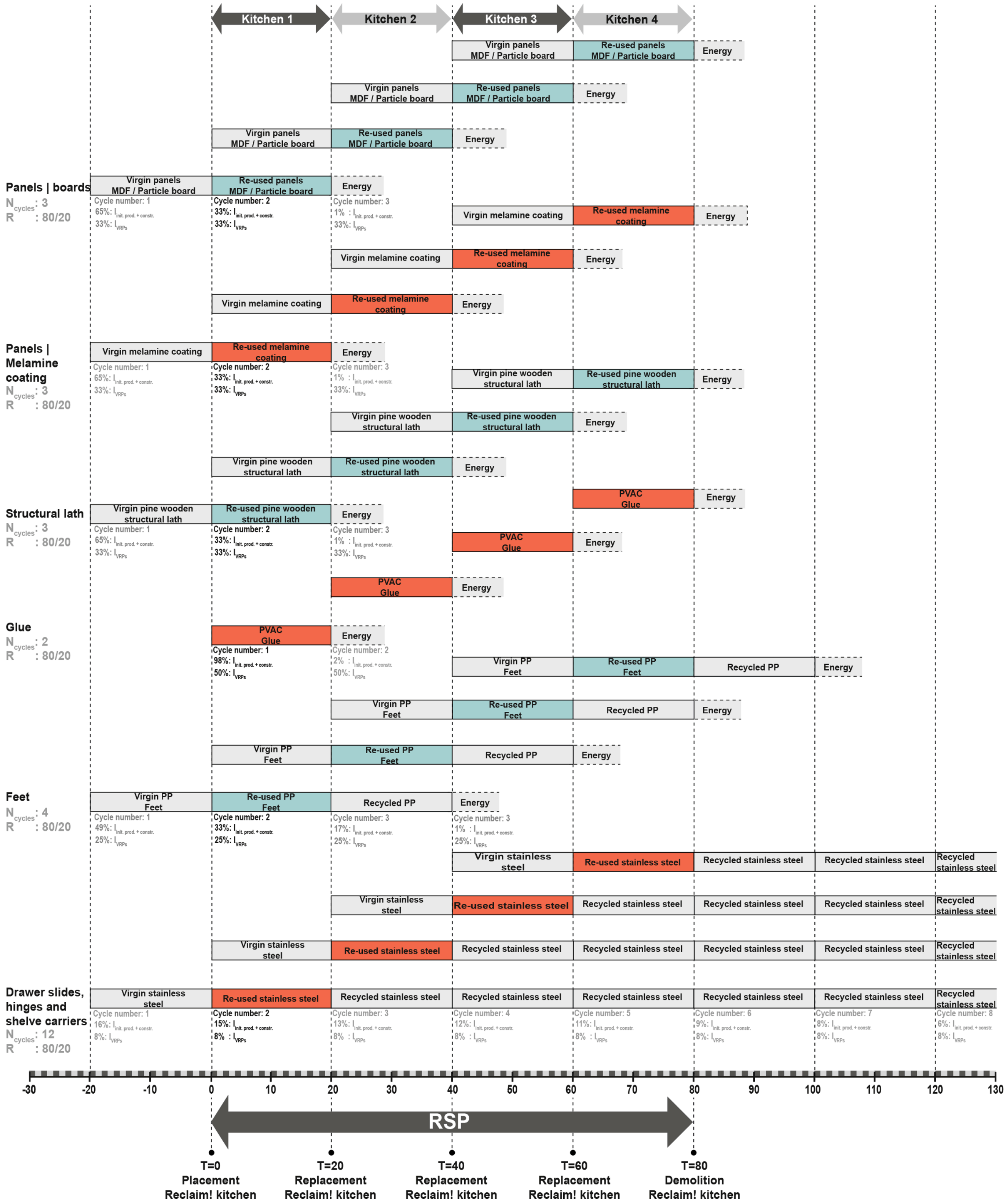


Fig. A4.2b. Distribution of impacts between use cycles of materials applied in the Reclaim! kitchen in relation to the RSP. (the green and red colour highlight the use cycles when the material is applied in the assessed kitchen).

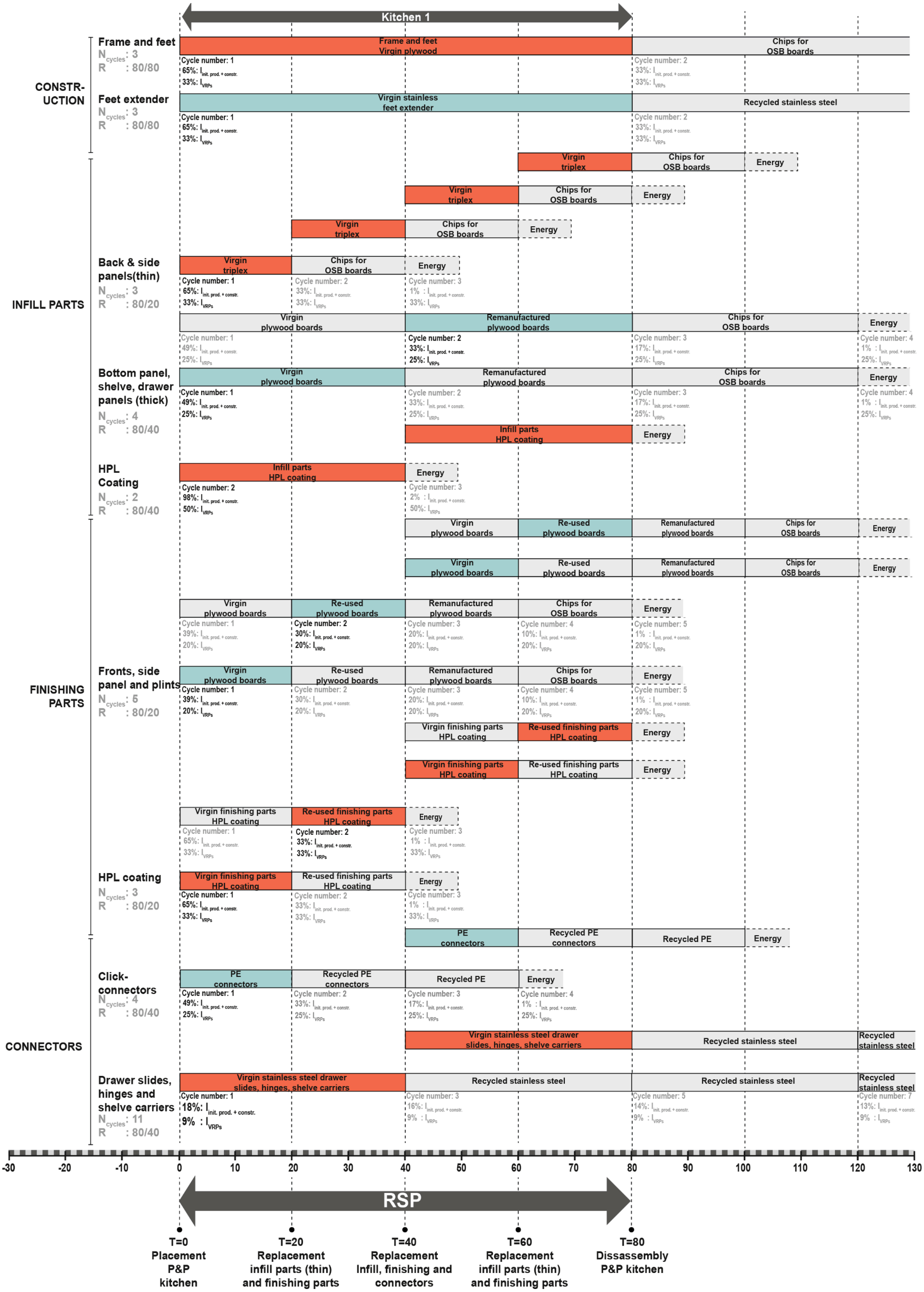


Fig. A4.2c. Distribution of impacts between use cycles of materials applied in the P&P kitchen in relation to the RSP (the green and red colour highlight the use cycles when the material is applied in the assessed kitchen).

Appendix 5. Sensitivity analysis scenarios

This appendix includes a detailed description of the sensitivity scenarios for the BAU, Reclaim! and P&P kitchen variants. Table A5.1 shows the 'what if question' tested per scenario; it gives the assumed N_{cycles} and $L_{technical}$ and $L_{functional}$ for (parts of) the kitchen variants, as well as the processes and parameters varied per scenario.

Table A5.1
Scenarios sensitivity analysis kitchen variants

Design variant	Scenario	Type of sensitivity scenario	What if question for scenario	Lifespan technical kitchen [years]	Lifespan technical kitchen [years]	Number of future, local, re-use cycles entire kitchen	What processes / parameters are varied
BAU	Baseline			20	20	0	
	C+1	N_{cycles}	What if the entire BAU kitchen would be re-used once locally?	20	20	1	Decrease allocation fractions for all materials*
	C+2	N_{cycles}	What if the entire BAU kitchen would be re-used twice locally?	20	20	2	Decrease allocation fractions for all materials*
	L7	$L_{technical}$ - $L_{functional}$	What if the BAU kitchen would already be replaced after 7 years?	7	7	0	Increase replacement rate for all materials*
	L40	$L_{technical}$ - $L_{functional}$	What if the BAU kitchen would only be replaced after 40 years?	40	40	0	Decrease replacement rate for all materials*
	L80	$L_{technical}$ - $L_{functional}$	What if the BAU kitchen would only be replaced after 80 years?	80	80	0	Decrease replacement rate for all materials*
Reclaim!	Baseline			10	10	0	
	C+1	N_{cycles}	What if the entire Reclaim! kitchen would be re-used once locally?	20	20	1	Decrease allocation fractions for all materials*
	C+2	N_{cycles}	What if the entire Reclaim! kitchen would be re-used twice locally?	20	20	2	Decrease allocation fractions for all materials*
	L7	$L_{technical}$ - $L_{functional}$	What if the Reclaim! kitchen would already be replaced after 7 years?	7	7	0	Increase replacement rate for all materials*
	L20	$L_{technical}$ - $L_{functional}$	What if the Reclaim! kitchen would last as long as the BAU kitchen?	20	20	0	Decrease replacement rate for all materials*
	L40	$L_{technical}$ - $L_{functional}$	What if the Reclaim! kitchen would only be replaced after 40 years?	40	40	0	Decrease replacement rate for all materials*
	L80	$L_{technical}$ - $L_{functional}$	What if the Reclaim! kitchen would only be replaced after 80 years?	80	80	0	Decrease replacement rate for all materials*

*For the values of each varied parameters per sensitivity scenario, we refer to the attachment 3

Design variant	Scenario	Type of sensitivity scenario	What if question for scenario	Lifespan technical kitchen parts [years]				Lifespan functional kitchen parts [years]				Number of future cycles removed	Number of additional direct, local re-use cycles entire kitchen	What processes / parameters are varied
				Construction	Infill	Finishing	Connectors	Construction	Infill	Finishing	Connectors			
P&P	Baseline			80	40	40	40	80	40	20	40	0	0	
	C-3	N_{cycles}	What if all of the outer (uncertain) future cycles of materials would r	80	40	40	40	80	40	20	40	3	0	Increase allocation fractions for materials of which future cycles are removed*; remove processes of removed outer cycles*
	C-2	N_{cycles}	What if the two most-outer (uncertain) future cycle of materials wou	80	40	40	40	80	40	20	40	2	0	Increase allocation fractions for materials of which future cycles are removed*; remove processes of removed outer cycles*
	C-1	N_{cycles}	What if the most-outer (uncertain) future cycle of materials would n	80	40	40	40	80	40	20	40	1	0	Increase allocation fractions for materials of which future cycles are removed*; remove processes of removed outer cycles*
	C+1	N_{cycles}	What if the entire P&P kitchen has one local re-use cycle additional to the baseline scenario?	80	40	40	40	80	40	20	40	0	1	Decrease allocation fractions for all materials*
	C+2	N_{cycles}	What if the entire P&P kitchen has two local re-use cycles additional to the baseline scenario?	80	40	40	40	80	40	20	40	0	2	Decrease allocation fractions for all materials*
	Lf=80-40-7-40, Lt=80-40-40-40	$L_{functional}$ (finishing parts)	What if the finishing parts of the kitchen would be already be (ex)changed after 7 years?	80	40	40	40	80	40	7	40	0	0	Increase replacement rate for all finishing materials*; decrease allocation fractions for all finishing materials (as the number of re-use cycles of the finishing parts increases)*
	Lf=80-40-40-40, Lt=80-40-40-40	$L_{functional}$ (finishing parts)	What if the finishing parts of the kitchen would only be (ex)changed after 40 years?	80	40	40	40	80	40	40	40	0	0	Decrease replacement rate for all finishing materials*; Increase allocation fractions for all finishing materials (as the number of re-use cycles of the finishing parts decreases)*
	Lt=7-7-7-7, Lf=7-7-3,5-7	$L_{technical}$ - $L_{functional}$	What if the entire kitchen lasts only ±7 years and the finishing parts are refurbished after ±3,5 years?	7	7	7	7	7	7	3.5	7	0	0	Increase replacement rate for all parts of the kitchen*
	Lt=20-20-20-20, Lf=20-20-10-20	$L_{technical}$ - $L_{functional}$	What if the P&P kitchen lasts as long as the BAU kitchen (with one refurbishment of the finishing parts at 10 years)?	20	20	20	20	20	20	10	20	0	0	Increase replacement rate for all parts of the kitchen*
	Lt=40-20-20-20, Lf=40-20-10-20	$L_{technical}$ - $L_{functional}$	What if the P&P kitchen lasts half as long and the finishing parts are (ex)changed twice as fast as the P&P baseline scenario?	40	20	20	20	40	20	10	20	0	0	Increase replacement rate for all parts of the kitchen*
	Lt=80-80-80-80, Lf=80-80-40-80	$L_{technical}$ - $L_{functional}$	What if the entire kitchen lasts 80 years and the finishing parts are refurbished after 40 years?	80	80	80	80	80	80	40	80	0	0	Decrease replacement rates for infill, finishing and connector parts of the kitchen*

*For the values of each varied parameters per sensitivity scenario, we refer to the attachment 3

Appendix 6. Results CE-LCIA sensitivity analysis

This appendix includes the results of the CE-LCIA for the sensitivity analysis of the BAU, Reclaim! and P&P kitchen variants. These results are discussed in Section 5.5.1 of this paper.

Table A6.1 presents the results per impact category for all sensitivity scenarios for all design variants. Table A6.2 shows the percentual reduction per scenario compared to the BAU baseline scenario for each impact category. Table A.6.3 shows the normalized values.

As an additional analysis, we illustrate how impacts are allocated to the kitchen over the RSP, for the sensitivity analysis on N_{cycles} in Figure A6.1 and for the sensitivity analysis on lifespan in Figure A6.2. Although this graph shows tipping points for the GWP, these tipping points can differ for other impact categories. Finally, for further clarification on each of the sensitivity scenarios, we refer to appendix 5.

Table A6.1
LCIA for all kitchen variants for all scenario

		BAU						Reclaim!						
Impact category	**Unit**	**Baseline**	**C+1**	**C+2**	**L7**	**L40**	**L80**	**Baseline**	**C+1**	**C+2**	**L7**	**L20**	**L40**	**L80**
Global warming potential	kg CO2 eq	1,48E+02	1,03E+02	8,25E+01	4,44E+02	7,41E+01	3,70E+01	1,50E+02	1,39E+02	1,22E+02	2,24E+02	7,48E+01	3,74E+01	1,87E+01
Ozone layer depletion potential	kg CFC-11 eq	1,32E-05	9,01E-06	7,00E-06	3,96E-05	6,60E-06	3,30E-06	1,12E-05	1,10E-05	9,99E-06	1,68E-05	5,59E-06	2,79E-06	1,40E-06
Photochemical oxidation potential	kg C2H4 eq	5,10E-02	3,62E-02	2,94E-02	1,53E-01	2,55E-02	1,27E-02	4,71E-02	4,65E-02	4,17E-02	7,07E-02	2,36E-02	1,18E-02	5,89E-03
Acidification potential	kg SO2 eq	5,99E-01	4,18E-01	3,32E-01	1,80E+00	2,99E-01	1,50E-01	5,34E-01	5,20E-01	4,67E-01	8,02E-01	2,67E-01	1,34E-01	6,68E-02
Eutrophication potential	kg PO4--- eq	2,22E-01	1,54E-01	1,23E-01	6,65E-01	1,11E-01	5,54E-02	1,98E-01	1,92E-01	1,71E-01	2,97E-01	9,92E-02	4,96E-02	2,48E-02
Abiotic depletion potential for elements	kg Sb eq	1,55E-03	1,07E-03	8,35E-04	4,65E-03	7,76E-04	3,88E-04	1,24E-03	1,22E-03	1,11E-03	1,86E-03	6,20E-04	3,10E-04	1,55E-04
Abiotic depletion potential for fossil fuels	MJ	1,81E+03	1,25E+03	9,76E+02	5,43E+03	9,05E+02	4,52E+02	1,56E+03	1,52E+03	1,37E+03	2,35E+03	7,82E+02	3,91E+02	1,96E+02
Fresh water aquatic ecotoxicity potential	kg 1,4-DB eq	8,30E+01	6,04E+01	4,95E+01	2,49E+02	4,15E+01	2,08E+01	9,37E+01	8,48E+01	7,51E+01	1,40E+02	4,68E+01	2,34E+01	1,17E+01
Human toxicity potential	kg 1,4-DB eq	1,82E+02	1,45E+02	1,26E+02	5,46E+02	9,10E+01	4,55E+01	2,37E+02	2,22E+02	2,03E+02	3,55E+02	1,18E+02	5,92E+01	2,96E+01
Marine aquatic ecotoxicity potential	kg 1,4-DB eq	1,70E+05	1,21E+05	9,71E+04	5,10E+05	8,51E+04	4,25E+04	1,71E+05	1,59E+05	1,41E+05	2,57E+05	8,56E+04	4,28E+04	2,14E+04
Terrestrial ecotoxicity potential	kg 1,4-DB eq	4,93E-01	3,59E-01	2,95E-01	1,48E+00	2,47E-01	1,23E-01	4,94E-01	4,75E-01	4,33E-01	7,42E-01	2,47E-01	1,24E-01	6,18E-02

		P&P										
Impact category	**Unit**	**Baseline**	**C-3**	**C-2**	**C-1**	**C+1**	**C+2**	**Lf=80-40-7-40, Lt=80-40-40-40**	**Lf=80-40-40-40, Lt=80-40-40-40**	**Lt=7-7-7-7, Lf=7-7-3,5-7**	**Lt=20-20-20-20, Lf=20-20-10-20**	**Lt=40-20-20-20, Lf=40-20-10-20**	**Lt=80-80-80-80, Lf=80-80-40-80**
Global warming potential	kg CO2 eq	6,40E+01	9,51E+01	7,13E+01	6,22E+01	5,22E+01	4,50E+01	7,85E+01	5,00E+01	4,01E+02	1,34E+02	1,28E+02	3,41E+01
Ozone layer depletion potential	kg CFC-11 eq	6,92E-06	1,18E-05	8,57E-06	7,23E-06	5,65E-06	4,80E-06	8,62E-06	5,22E-06	4,34E-05	1,45E-05	1,38E-05	3,73E-06
Photochemical oxidation potential	kg C2H4 eq	2,54E-02	4,19E-02	3,13E-02	2,62E-02	2,10E-02	1,83E-02	3,07E-02	2,00E-02	1,60E-01	5,34E-02	5,06E-02	1,37E-02
Acidification potential	kg SO2 eq	2,99E-01	4,84E-01	3,57E-01	3,01E-01	2,46E-01	2,12E-01	3,67E-01	2,32E-01	1,89E+00	6,30E-01	5,97E-01	1,61E-01
Eutrophication potential	kg PO4--- eq	1,05E-01	1,64E-01	1,22E-01	1,03E-01	8,69E-02	7,49E-02	1,30E-01	8,20E-02	6,67E-01	2,22E-01	2,10E-01	5,67E-02
Abiotic depletion potential for elements	kg Sb eq	9,77E-04	3,83E-04	2,98E-04	2,66E-04	8,25E-04	7,09E-04	1,34E-03	7,52E-04	6,41E-03	2,14E-03	1,95E-03	5,37E-04
Abiotic depletion potential for fossil fuels	MJ	7,88E+02	1,27E+03	9,27E+02	7,92E+02	6,43E+02	5,49E+02	9,69E+02	6,05E+02	4,94E+03	1,65E+03	1,57E+03	4,23E+02
Fresh water aquatic ecotoxicity potential	kg 1,4-DB eq	3,73E+01	3,84E+01	3,12E+01	2,86E+01	3,11E+01	2,72E+01	4,56E+01	3,08E+01	2,39E+02	7,96E+01	7,46E+01	2,01E+01
Human toxicity potential	kg 1,4-DB eq	9,11E+01	9,79E+01	8,64E+01	8,17E+01	7,85E+01	7,10E+01	1,02E+02	8,23E+01	5,88E+02	1,96E+02	1,82E+02	4,93E+01
Marine aquatic ecotoxicity potential	kg 1,4-DB eq	7,62E+04	8,55E+04	6,60E+04	5,83E+04	6,32E+04	5,47E+04	9,48E+04	6,09E+04	4,86E+05	1,62E+05	1,52E+05	4,10E+04
Terrestrial ecotoxicity potential	kg 1,4-DB eq	2,81E-01	3,53E-01	2,73E-01	2,36E-01	2,36E-01	2,05E-01	3,45E-01	2,27E-01	1,80E+00	6,00E-01	5,62E-01	1,52E-01

Table A6.2
Percentual reduction per design variant scenario compared to the BAU baseline scenario

	BAU						Reclaim!						
Impact category	**Baseline**	**C+1**	**C+2**	**L7**	**L40**	**L80**	**Baseline**	**C+1**	**C+2**	**L7**	**L20**	**L40**	**L80**
Global warming potential	0%	30%	44%	-200%	50%	75%	-1%	6%	18%	-51%	50%	75%	87%
Ozone layer depletion potential	0%	32%	47%	-200%	50%	75%	15%	16%	24%	-27%	58%	79%	89%
Photochemical oxidation potential	0%	29%	42%	-200%	50%	75%	7%	9%	18%	-39%	54%	77%	88%
Acidification potential	0%	30%	45%	-200%	50%	75%	11%	13%	22%	-34%	55%	78%	89%
Eutrophication potential	0%	30%	45%	-200%	50%	75%	11%	14%	23%	-34%	55%	78%	89%
Abiotic depletion potential for elements	0%	31%	46%	-200%	50%	75%	20%	21%	28%	-20%	60%	80%	90%
Abiotic depletion potential for fossil fuels	0%	31%	46%	-200%	50%	75%	14%	16%	24%	-30%	57%	78%	89%
Fresh water aquatic ecotoxicity potential	0%	27%	40%	-200%	50%	75%	-13%	-2%	9%	-69%	44%	72%	86%
Human toxicity potential	0%	21%	31%	-200%	50%	75%	-30%	-22%	-12%	-95%	35%	67%	84%
Marine aquatic ecotoxicity potential	0%	29%	43%	-200%	50%	75%	-1%	7%	17%	-51%	50%	75%	87%
Terrestrial ecotoxicity potential	0%	27%	40%	-200%	50%	75%	0%	4%	12%	-50%	50%	75%	87%

	P&P											
Impact category	**Baseline**	**C-3**	**C-2**	**C-1**	**C+1**	**C+2**	**Lf=80-40-7-40, Lt=80-40-40-40**	**Lf=80-40-40-40, Lt=80-40-40-40**	**Lt=7-7-7-7, Lf=7-7-3,5-7**	**Lt=20-20-20-20, Lf=20-20-10-20**	**Lt=40-20-20-20, Lf=40-20-10-20**	**Lt=80-80-80-80, Lf=80-80-40-80**
Global warming potential	57%	36%	52%	58%	65%	70%	47%	66%	-171%	10%	14%	77%
Ozone layer depletion potential	48%	10%	35%	45%	57%	64%	35%	60%	-229%	-10%	-4%	72%
Photochemical oxidation potential	50%	18%	39%	49%	59%	64%	40%	61%	-214%	-5%	1%	73%
Acidification potential	50%	19%	40%	50%	59%	65%	39%	61%	-216%	-5%	0%	73%
Eutrophication potential	53%	26%	45%	54%	61%	66%	41%	63%	-201%	0%	5%	74%
Abiotic depletion potential for elements	37%	75%	81%	83%	47%	54%	14%	52%	-313%	-38%	-26%	65%
Abiotic depletion potential for fossil fuels	56%	30%	49%	56%	64%	70%	46%	67%	-173%	9%	13%	77%
Fresh water aquatic ecotoxicity potential	55%	54%	62%	66%	62%	67%	45%	63%	-188%	4%	10%	76%
Human toxicity potential	50%	46%	53%	55%	57%	61%	44%	55%	-223%	-8%	0%	73%
Marine aquatic ecotoxicity potential	55%	50%	61%	66%	63%	68%	44%	64%	-186%	5%	11%	76%
Terrestrial ecotoxicity potential	43%	28%	45%	52%	52%	58%	30%	54%	-265%	-22%	-14%	69%

Note: The colour shows a gradient between the highest percentual savings (green) and lowest percentual savings (red) over all design variants and scenarios, per impact category.

Table A6.3
Normalised impacts for each sensitivity scenario per impact category

	BAU						Reclaim!						
Impact category	**Baseline**	**C+1**	**C+2**	**L7**	**L40**	**L80**	**Baseline**	**C+1**	**C+2**	**L7**	**L20**	**L40**	**L80**
Global warming potential	3,54E-12	2,47E-12	1,97E-12	1,06E-11	1,77E-12	8,86E-13	3,58E-12	3,32E-12	2,92E-12	5,37E-12	1,79E-12	8,95E-13	4,47E-13
Ozone layer depletion potential	5,81E-14	3,97E-14	3,08E-14	1,74E-13	2,91E-14	1,45E-14	4,92E-14	4,87E-14	4,40E-14	7,38E-14	2,46E-14	1,23E-14	6,15E-15
Photochemical oxidation potential	1,39E-12	9,83E-13	7,98E-13	4,16E-12	6,93E-13	3,46E-13	1,28E-12	1,26E-12	1,13E-12	1,92E-12	6,41E-13	3,20E-13	1,60E-13
Acidification potential	2,50E-12	1,75E-12	1,39E-12	7,51E-12	1,25E-12	6,26E-13	2,24E-12	2,17E-12	1,95E-12	3,35E-12	1,12E-12	5,59E-13	2,80E-13
Eutrophication potential	1,40E-12	9,78E-13	7,78E-13	4,21E-12	7,02E-13	3,51E-13	1,26E-12	1,21E-12	1,09E-12	1,88E-12	6,28E-13	3,14E-13	1,57E-13
Abiotic depletion potential for elements	7,42E-12	5,11E-12	3,99E-12	2,23E-11	3,71E-12	1,86E-12	5,93E-12	5,84E-12	5,32E-12	8,90E-12	2,97E-12	1,48E-12	7,42E-13
Abiotic depletion potential for fossil fuels	4,76E-12	3,28E-12	2,57E-12	1,43E-11	2,38E-12	1,19E-12	4,12E-12	4,01E-12	3,60E-12	6,18E-12	2,06E-12	1,03E-12	5,15E-13
Fresh water aquatic ecotoxicity potential	3,52E-11	2,56E-11	2,10E-11	1,06E-10	1,76E-11	8,79E-12	3,97E-11	3,59E-11	3,18E-11	5,95E-11	1,98E-11	9,92E-12	4,96E-12
Human toxicity potential	7,05E-11	5,60E-11	4,90E-11	2,12E-10	3,53E-11	1,76E-11	9,18E-11	8,61E-11	7,89E-11	1,38E-10	4,59E-11	2,29E-11	1,15E-11
Marine aquatic ecotoxicity potential	8,77E-10	6,23E-10	5,01E-10	2,63E-09	4,39E-10	2,19E-10	8,82E-10	8,17E-10	7,27E-10	1,32E-09	4,41E-10	2,21E-10	1,10E-10
Terrestrial ecotoxicity potential	4,52E-13	3,30E-13	2,71E-13	1,36E-12	2,26E-13	1,13E-13	4,54E-13	4,36E-13	3,97E-13	6,80E-13	2,27E-13	1,13E-13	5,67E-14

Note: The colour shows a gradient between the highest (red) and lowest (green) value per scenario per design variant.

	P&P											
Impact category	**Baseline**	**C-3**	**C-2**	**C-1**	**C+1**	**C+2**	**Lf=80-40-7-40, Lt=80-40-40-40**	**Lf=80-40-40-40, Lt=80-40-40-40**	**Lt=7-7-7-7, Lf=7-7-3,5-7**	**Lt=20-20-20-20, Lf=20-20-10-20**	**Lt=40-20-20-20, Lf=40-20-10-20**	**Lt=80-80-80-80, Lf=80-80-40-80**
Global warming potential	1,53E-12	2,28E-12	1,71E-12	1,49E-12	1,25E-12	1,08E-12	1,88E-12	1,20E-12	9,59E-12	3,20E-12	3,05E-12	8,17E-13
Ozone layer depletion potential	3,05E-14	5,22E-14	3,78E-14	3,18E-14	2,49E-14	2,11E-14	3,80E-14	2,30E-14	1,91E-13	6,37E-14	6,06E-14	1,64E-14
Photochemical oxidation potential	6,89E-13	1,14E-12	8,50E-13	7,13E-13	5,71E-13	4,98E-13	8,35E-13	5,44E-13	4,35E-12	1,45E-12	1,38E-12	3,72E-13
Acidification potential	1,25E-12	2,02E-12	1,49E-12	1,26E-12	1,03E-12	8,85E-13	1,54E-12	9,72E-13	7,90E-12	2,63E-12	2,50E-12	6,75E-13
Eutrophication potential	6,66E-13	1,04E-12	7,72E-13	6,50E-13	5,50E-13	4,74E-13	8,23E-13	5,19E-13	4,22E-12	1,41E-12	1,33E-12	3,59E-13
Abiotic depletion potential for elements	4,67E-12	1,83E-12	1,43E-12	1,27E-12	3,95E-12	3,39E-12	6,41E-12	3,60E-12	3,07E-11	1,02E-11	9,35E-12	2,57E-12
Abiotic depletion potential for fossil fuels	2,07E-12	3,34E-12	2,44E-12	2,08E-12	1,69E-12	1,44E-12	2,55E-12	1,59E-12	1,30E-11	4,34E-12	4,13E-12	1,11E-12
Fresh water aquatic ecotoxicity potential	1,58E-11	1,63E-11	1,32E-11	1,21E-11	1,32E-11	1,15E-11	1,93E-11	1,30E-11	1,01E-10	3,37E-11	3,16E-11	8,51E-12
Human toxicity potential	3,53E-11	3,79E-11	3,35E-11	3,17E-11	3,04E-11	2,75E-11	3,95E-11	3,19E-11	2,28E-10	7,59E-11	7,06E-11	1,91E-11
Marine aquatic ecotoxicity potential	3,93E-10	4,41E-10	3,40E-10	3,00E-10	3,26E-10	2,82E-10	4,89E-10	3,14E-10	2,51E-09	8,36E-10	7,85E-10	2,11E-10
Terrestrial ecotoxicity potential	2,58E-13	3,24E-13	2,51E-13	2,17E-13	2,16E-13	1,89E-13	3,17E-13	2,09E-13	1,65E-12	5,50E-13	5,16E-13	1,40E-13

Note: The colour shows a gradient between the highest (red) and lowest (green) value per scenario per design variant.

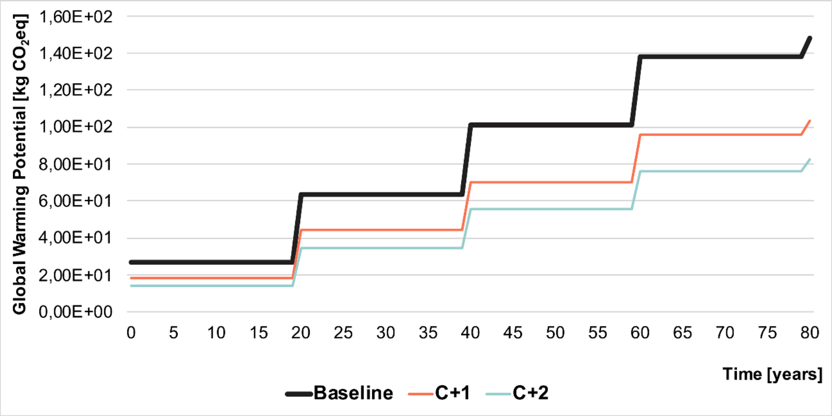


Fig. A6.1a. Sensitivity analysis on the number of cycles for the BAU kitchen (GWP over 80 years).

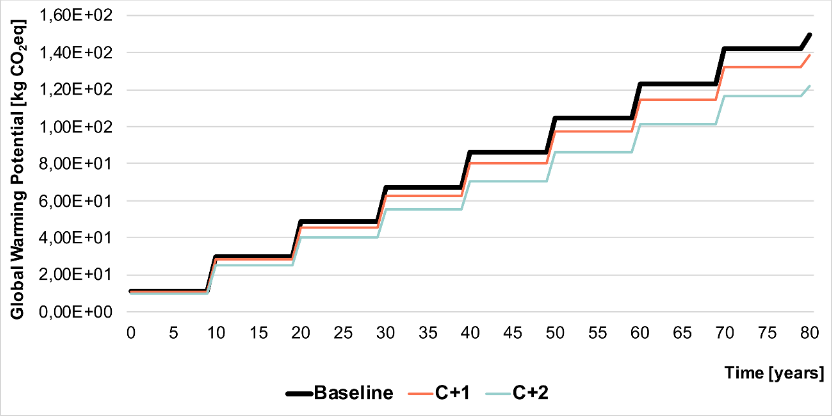


Fig. A6.1b. Sensitivity analysis on the number of cycles for the Reclaim! kitchen (GWP over 80 years).

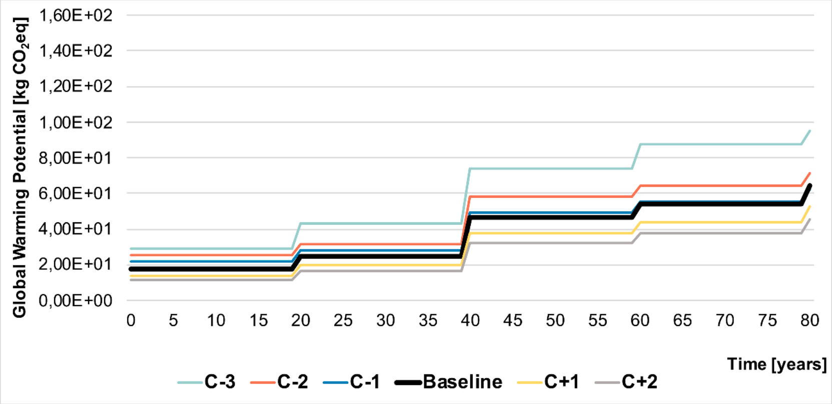


Fig. A6.1c. Sensitivity analysis on the number of cycles for the P&P kitchen (GWP over 80 years).

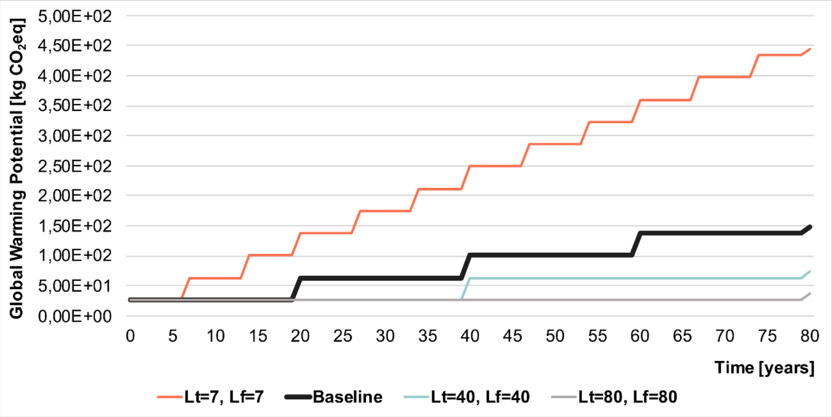


Fig. A6.2a. Sensitivity analysis on the $L_{technical}$ and $L_{functional}$ for the BAU kitchen (GWP over 80 years).

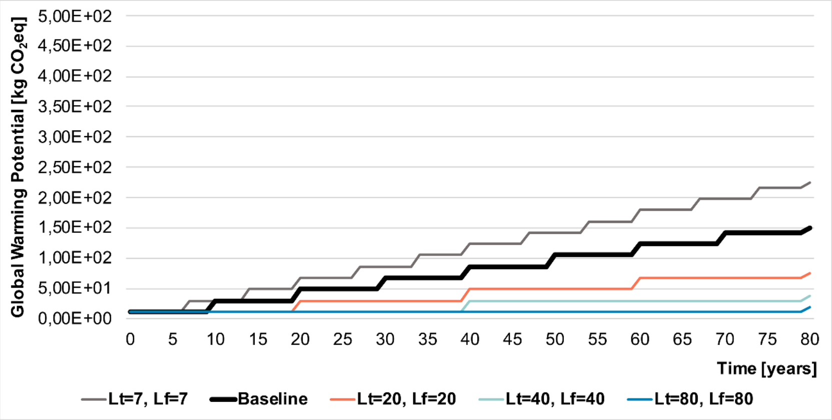


Fig. A6.2b. Sensitivity analysis on the $L_{technical}$ and $L_{functional}$ for the Reclaim! kitchen (GWP over 80 years).

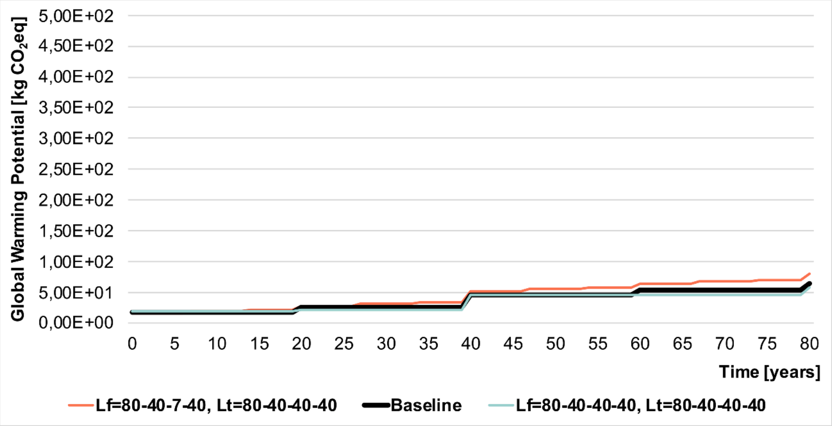


Fig. A6.2c. Sensitivity analysis on the $L_{functional}$ for the finishing of the Plug-and-play kitchen (GWP over 80 years).

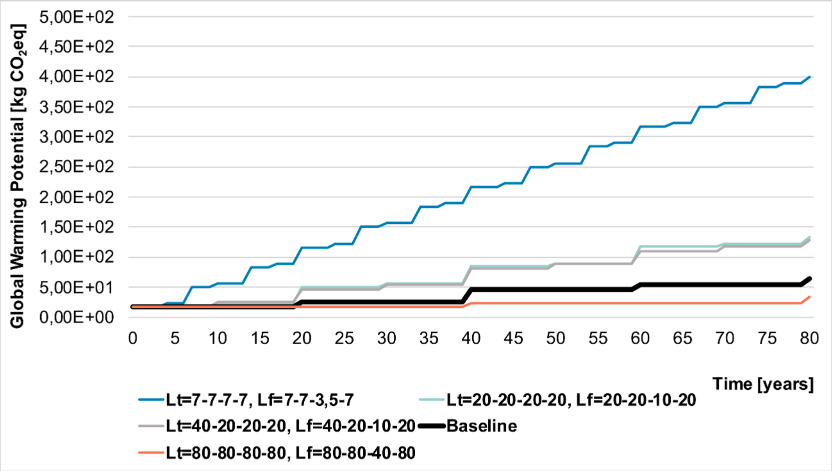


Fig. A6.2d. Sensitivity analysis on the $L_{technical}$ and $L_{functional}$ for the Plug-and-play kitchen (GWP over 80 years).

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