Carbon footprint repairing versus replacing of window frames

Public report

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REPAIR CARE

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Content

Executive summary

Goals and scope

The goal of this project is to compare the cradle-to-grave carbon footprint associated with the repair of a damaged wooden window frame, with the carbon footprint associated with the replacement of this window frame.

For the repair of the damaged window frames, we focus on the use of two alternative repair resins from Repair Care: DRY FLEX® 4 and BIO FLEX™ ALLROUND. The use of DRY FIX® UNI is taken into account as well, as this primer is used to prepare the damaged wood for the application of the repair resin. Four types of repair are included, from simple preventative maintenance to extensive curative repairs:

- joint repair (P2);
- corner repair (C1/5);
- timber insert (C2/25);
- splicing repair (C4/25).

For the replacement of the damaged wooden window frames, we include new window frames made from hardwood, softwood, aluminium and PVC.

We carry out all calculations according to the Bepalingsmethode, a uniform LCA method to calculate the environmental performance of building materials and structures in an unambiguous, verifiable and reproducible way[1]. During these calculations we use background data from Carbon Minds 2021, as this database is specifically designed for chemicals and is based on recent data (0-5 years old). Background data from ecoinvent 3.8 cut-off is used to fill in any data gaps.

Main results and recommendations

The results of this study show that repairing a damaged wooden window frame with Repair Care resins DRY FLEX® 4 of BIO FLEX™ ALLROUND is associated with a significantly lower carbon footprint over its lifetime (Module A1-D) than replacement (see Figure 1 without glass and Figure 2 with glass). The figures show the most severe repair type (splicing repair, C4/25).

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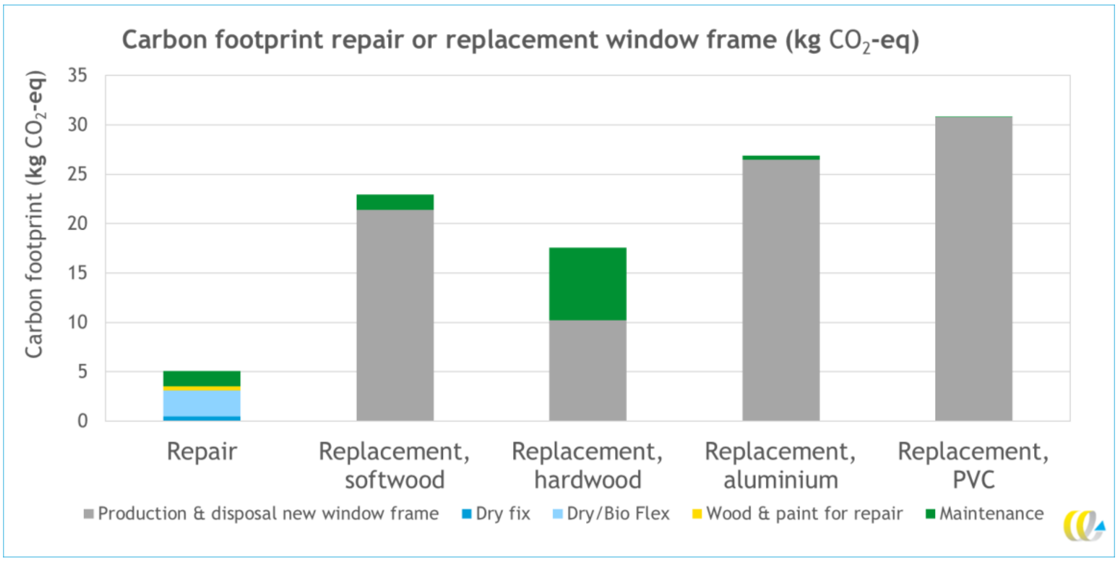
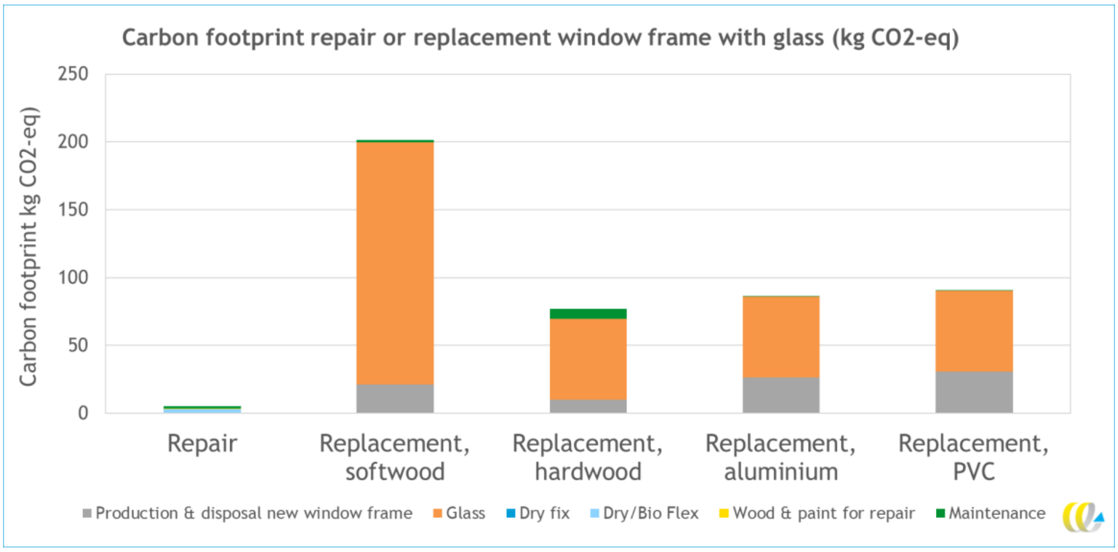
[1] Milieudatabase: The Environmental Performance Assessment Method for Construction Works

Figure 1 - Carbon footprint of *softwood* window frame repair and replacement, entire life cycle (Module A1-D, during 25 years, excluding waste disposal of original repaired/replaced wooden frame), *excluding* glass*



* Figure has been simplified and adapted to an average carbon footprint per material for this public report.

Figure 2 - Carbon footprint of *softwood* window frame repair and replacement, entire life cycle (Module A1-D, during 25 years, excluding waste disposal of original repaired/replaced wooden frame), *including* glass*



* Figure has been simplified and adapted to an average carbon footprint per material for this public report.

Even when the most severe repair type (splicing repair, C4/25) is carried out multiple times on a single window frame, the carbon footprint of this repair would still be lower than the carbon footprint of a replacement with a window frame with the lowest carbon footprint (hardwood). In fact, the carbon footprint of the repair is relatively low, compared to the maintenance of the repaired window frame during its extended lifetime.

When the replacement of glass in the window frames is taken into account as well, the carbon footprint of the replacement scenarios window frames increases quite dramatically. This makes repair of damaged window frames even more preferable than replacement.

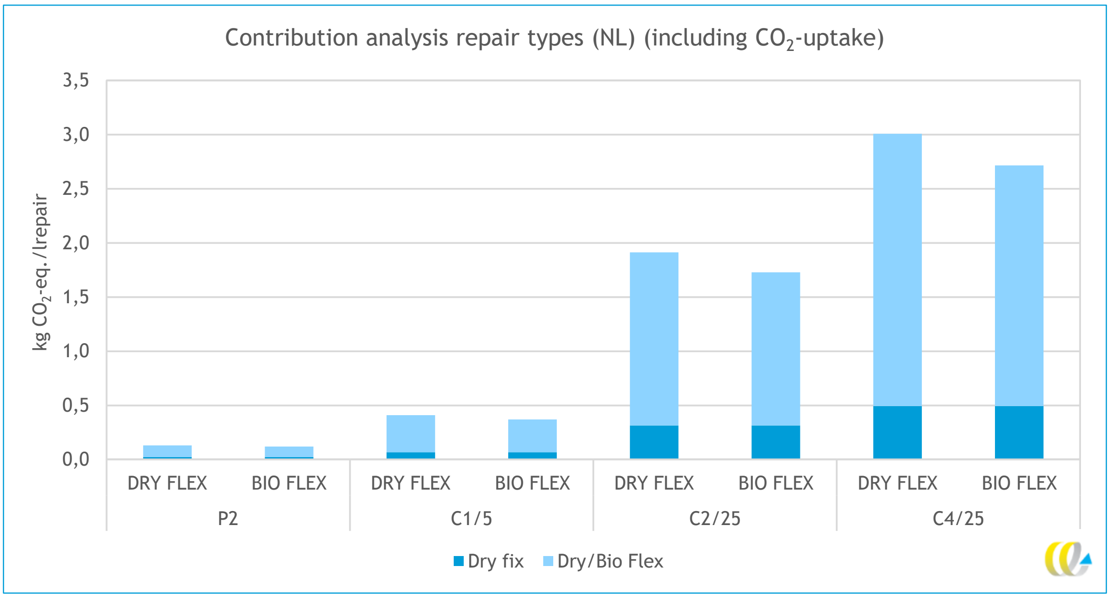
The results are sensitive to changing background data (Carbon Minds or ecoinvent) for ingredients of the Repair Care products and to a lesser extent to assumptions about the energy consumption in stoichiometric calculations for these ingredients. While this does not affect the overall conclusion of this study, the individual carbon footprints of the Repair Care products themselves are associated with some uncertainty.

We therefore recommend to improve this study by obtaining more supplier-specific LCA data for the ingredients of the Repair Care products, such as EPD's and LCA studies. We also recommend to update this LCA study to the latest LCA norm for window frames (EN17213), when LCA studies on new windows frames carried our according to the EN17213 LCA norm becomes available. This will allow the comparison of repairs with Repair Care products to stay up-to-date and relevant.

Repair types (Module A1-A5)

When zooming in on the individual repair types (Figure 3), it becomes clear their carbon footprint is predominantly associated with the repair resins (DRY FLEX® 4 or BIO FLEX™ ALLROUND). DRY FIX® UNI contributes only 16% to the carbon footprint of these repairs, as it is applied in less volume than the repair resins. The carbon footprint of repairs carried out with BIO FLEX™ ALLROUND is 3% lower than repairs carried out with DRY FLEX® 4, but is 10% lower when the benefit of biogenic content in the resins is taken into account.

Figure 3 - Contribution analysis repair types, per applied Repair Care product (Module A1-A5, including benefit biogenic carbon content)

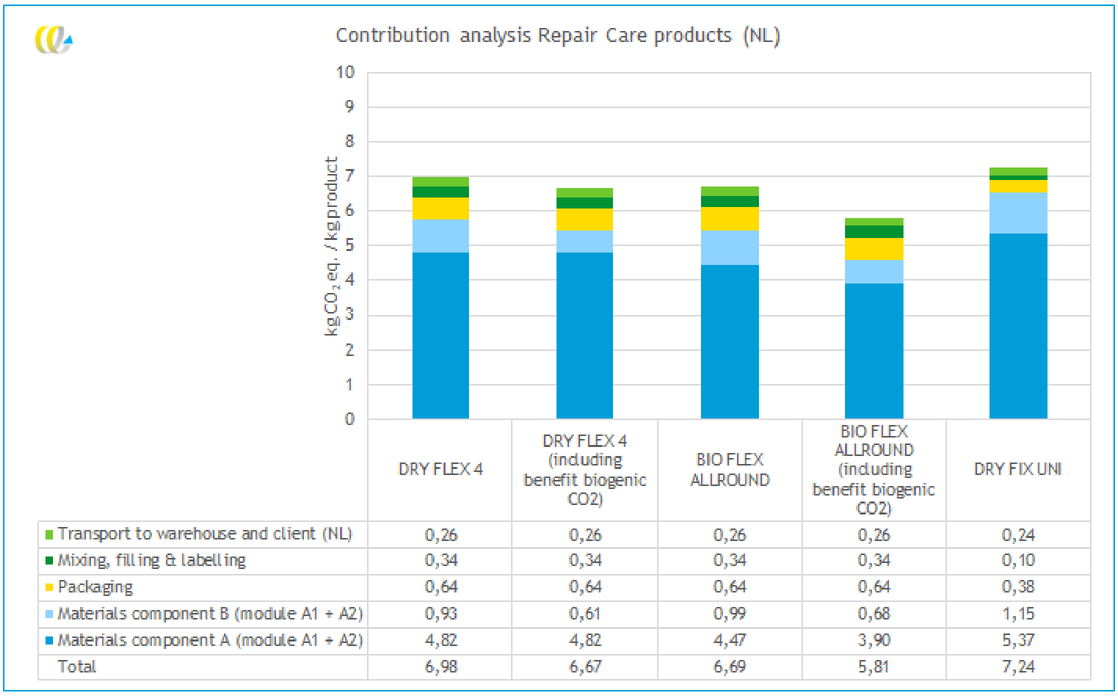


The difference between the carbon footprint of DRY FLEX® 4 and BIO FLEX™ ALLROUND in this study is sensitive to the type of background data used, however the carbon footprint of repairs carried out DRY FLEX® 4 can become slightly lower than BIO FLEX™ ALLROUND, depending on the background data.

Production of Repair Care products (Module A1- A4)

When we zoom in further on the production of the Repair Care products themselves, we can see component A contributes most to the carbon footprint of all Repair Care products (Figure 3). This is largely due to the fact that component A is used in higher volumes per repair than component B, but also because component A has a higher impact per kg than component B. Packaging only contributes around 5-10% to the total carbon footprint, while transport only contributes 3-4%.

Figure 3 - Carbon footprint and contribution analysis Repair Care products (NL), per kg product, excluding application (Module A1-A4, excluding and including a benefit for biogenic carbon content)



	DRY FLEX 4	DRY FLEX 4 (including benefit biogenic CO2)	BIO FLEX ALLROUND	BIO FLEX ALLROUND (including benefit biogenic CO2)	DRY FIX UNI
🟩 Transport to warehouse and client (NL)	0,26	0,26	0,26	0,26	0,24
🟩 Mixing, filling & labelling	0,34	0,34	0,34	0,34	0,10
🟨 Packaging	0,64	0,64	0,64	0,64	0,38
🟦 Materials component B (module A1 + A2)	0,93	0,61	0,99	0,68	1,15
🟦 Materials component A (module A1 + A2)	4,82	4,82	4,47	3,90	5,37
Total	6,98	6,67	6,69	5,81	7,24

The carbon footprint of BIO FLEX™ ALLROUND per kg resin is 4% lower than DRY FLEX® 4. This difference increases to 12.5% when the benefit of biogenic content in the resins is taken into account. The difference between the carbon footprint of DRY FLEX® 4 and BIO FLEX™ ALLROUND in this study is also sensitive to the type of background data used.

This sensitivity does not influence the overall conclusion of this study that repairing a damaged wooden window frame is associated with a significantly lower carbon footprint than replacing it with a new window frame.

1 Introduction

Many homes in Europe contain wooden window frames. Over time, these window frames require care and maintenance to protect the wood from the elements. When damages in the paint or wood are not taken care of in time, wood decay can occur.

Wood decay in window frames is usually located in the bottom 20-30 cm of window frames[2]. Joints in the lower part of the window frames are especially vulnerable, as water is most prone to enter the wood here and cause the wood to start decaying. This can lead to the replacement of the damaged window frame, even though the majority of the wood is located higher up in the window frame and is still in good condition. An alternative to replacement is to repair the window frame, which allows the undamaged fraction of the window frames to be preserved.

In this report we investigate the environmental benefits of repairing damaged wooden window frames with Repair Care resin, compared to replacement. We investigate several repair types, from slight to heavy damage.

1.1 Reading guide

In Chapter 2 we go into the goal of this LCA study, after which we describe the repair types, products and window frames we take into account. We also go into the scope and system boundaries of this study, as well as the methodology we apply.
In Chapter 3 we show the results of the LCA study. First we show the carbon footprint per kg Repair Care product, after which we go into the carbon footprint of the repair types. Then we show the comparison between repairing and replacing wooden window frames for several scenarios. Because all replacement scenarios also require the replacement of the glass windows, we also go into the potential influence these glass windows can have on the comparison. Finally, we carry out a sensitivity analysis to investigate if changing the background data and assumptions we use could affect the conclusions of this study.
In Chapter 4 we provide all background data, assumptions and modelling choices that we use to carry out the LCA.
Detailed insight into the composition of the Repair Care products and their contribution to the carbon footprint is provided in the annexes. These annexes contain confidential information and are therefore only delivered to authorised employees of Repair Care.

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[2] Research by Repair Care.

2 Goal and scope

The goal of this project is to compare the carbon footprint associated with the repair of a damaged wooden window frame, with the carbon footprint associated with the replacement of this window frame. We calculate carbon footprints by carrying out an LCA (Life Cycle Assessment) from cradle-to-grave. The repairs are carried out with Repair Care resins.

This project encompasses two types of repair resin, four types of repairs of wooden window frames and three types of new window frames to replace the wooden window frames.

2.1 Description of Repair Care resins

During this LCA we focus on two repair resins of Repair Care used to repair damaged wooden window frames:
- DRY FLEX® 4;
- BIO FLEX™ ALLROUND.

We also include DRY FIX® UNI primer. This is an impregnation agent that is used to prepare the wood for the application of DRY FIX® or BIO FLEX™ for a repair. All Repair Care products are described hereafter.

2.1.1 DRY FLEX® 4

DRY FLEX® 4 is an elastic repair compound for fast timber repairs and splicing (paintable after four hours). This is the most popular repair resin of Repair Care across the UK, Germany and the Netherlands. Ideal for the permanent repair of decayed and damaged wood. It behaves like wood: the product can be re-worked and painted in the same way and moves with the wood.

The components DRY FLEX® 4 are applied at a ratio of 3 ml component A to 1 ml component B.

2.1.2 BIO FLEX™ ALLROUND

BIO FLEX™ ALLROUND elastic repair is the first certified epoxy wood repair resin with 40% biobased raw materials for all types of repairs, all year round without losing its elastic characteristics. Ideal for the permanent repair of all types of wood rot and damage throughout the year. It behaves like wood: the product can be re-worked and painted in the same way and moves with the wood.

The components of BIO FLEX™ ALLROUND are applied at a ratio of 3 ml component A to 1 ml component B.

2.1.3 DRY FIX® UNI primer

DRY FIX® UNI is a universal wood stabiliser for all DRY FLEX® repair products. It ensures maximum adhesion between any DRY FLEX® repair product and the substrate. Repairs with any DRY FLEX® and BIO FLEX™ can be completed up to 24 hours after application of DRY FIX® UNI. It has low viscosity (solvent free) which enables to penetrate quickly and deeply into the wood.

DRY FIX® is applied at a ratio between 1 ml DRY FIX® UNI to 5-10 ml FLEX (either DRY FLEX® 4 OR BIO FLEX™ ALLROUND). The components of BIO FLEX™ ALLROUND are applied at a ratio of 2 ml component A to 1 ml component B.

2.2 Description of repair types

Repair Care has provided information about four common types of repairs, from preventative maintenance to curative maintenance/repair:

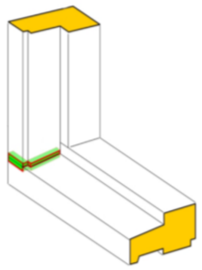
- Preventative maintenance:
  - joint repair (P2).
- Curative maintenance/repair:
  - corner repair (C1/5);
  - timber insert (C2/25);
  - splicing repair (C4/25).

A short description of each repair type is given in the next sections.

2.2.1 Joint repair

The joint repair is preventative maintenance, during which repair open joints are sealed to prevent further rot or decay (Figure 5).

Figure 5 - Visualisation of joint repair (P2)



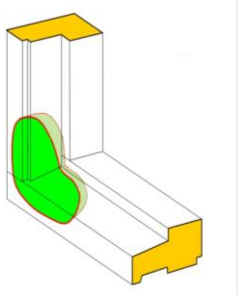
Source: Repair Care.

Using a high-speed router, joints are opened along the whole length to a minimum of 10 mm wide and 10 mm deep. After ensuring the moisture content is not too high, the DRY FIX® UNI wood stabiliser is applied. Once this is done there is a time window of 24 hours to apply the selected DRY FLEX® resin into the repair area. When the resin compound is completely cured the area can be sanded to ensure a smooth finish and to give a key for the decorative coating.

2.2.2 Corner repair

The corner repair is a curative repair where the wood decay in the corner of a window is restored (Figure 6).

Figure 6 - Visualisation of corner repair (C1/5)



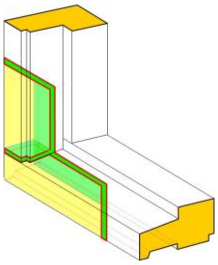
Source: Repair Care.

This is the most common repair for which the Repair Care resins are used. A standard working procedure is followed, which entails routing, measuring moisture content, applying resin and sanding.

2.2.3 Timber insert

The timber insert is a curative repair for larger damages where a large area needs be filled (Figure 7).

Figure 7 - Visualisation of timber insert (C2/25)



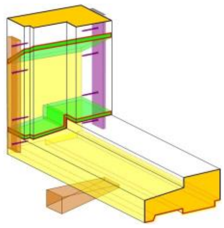
Source: Repair Care.

For this type of repair it is best to remove all the rotten wood up to the undamaged layers. To fill up the area that remains, a new component of wood is put in and fixed with epoxy resin.

2.2.4 Splicing repair

The splicing repair is a curative repair to treat advanced wood decay (Figure 8).

Figure 8 - Visualisation of splicing repair (C4/25)



Source: Repair Care.

If the wood decay is in an advanced stage, a splicing repair might be necessary to replace part of the frame such as the sill or the stile. This is an extensive repair but less costly than replacing the whole window. For this type of repair the glazing of the window has to be taken out before and placed back after the repair. The window parts that are damaged are taken out and replaced by new parts and fixed with epoxy resin.

2.3 Description of window frames

A damaged wooden window frame can be replaced by a myriad of new frames. During this LCA, we focus on three types of fixed (non-opening) window frames for exterior use:

- wooden window frames;
- aluminium window frames;
- PVC window frames.

The carbon footprint of these window frames can differ, depending on their composition and underlying LCA study. We therefore include the carbon footprint of several options per window frame type. The window frames are described in the next sections.

2.3.1 Wooden window frames

The wooden window frames are prefabricated and painted in the Netherlands. In this study we present the carbon footprint of one window frame from average European softwood, one from average African hardwood and one from average South-American hardwood. Their carbon footprint is based on publicly available verified Category 2[3] EPD’s from NBvT ((NBvT, 2016a, 2016b, 2016c)). In line with the Bepalingsmethode (see Section 2.6), uptake of biogenic CO_2 by wood is not taken into account. According to the EPD’s from NBvT the lifetime of the window frames from softwood (25 years) are significantly shorter than of the hardwood variants (75 years). This also influences the maintenance, as extensive maintenance only takes place after 40 years and therefore is not present for the window frames from softwood. For more information about the maintenance, see the EPD’s of NBvT (NBvT, 2016a, 2016b, 2016c) and Section 2.5.

Based on their experience and expertise, Repair Care has indicated the reported lifetimes for wooden window frames appear to be relatively high given the relative low amount of maintenance. We will conform to the lifetimes of 25 and 75 years, however, as these are the lifetimes that are reported in the verified LCA studies with which we compare the impact on climate change of window frame repair.

2.3.2 Aluminium window frames

The aluminium window frames are produced and powder coated in the Netherlands. In this study we present the carbon footprint of two window frames made from coated aluminium. Their carbon footprint is based on a verified Category 2 LCA study from SGS Search (2018) commissioned by VMRG and VKG, and Category 3 data from the NMD (2016), respectively.

Only limited maintenance is reported in the verified LCA study. Based on their experience and expertise, Repair Care has indicated they expect more maintenance might be required to ensure the window frames will reach their 75 year lifetime. However, we will conform to

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[3] Data categories according to the Bepalingsmethode: Category 1 (brand-specific data), Category 2 (branch-specific data, or data from a group of manufacturers/suppliers), Category 3 (unbranded data, drafted by LCA-experts from the NMD).

the maintenance indicated in the verified LCA studies with which we compare the impact on climate change of window frame repair.

2.3.3 PVC window frames

The PVC window frames are produced and powder coated in the Netherlands. In this study we present the carbon footprint of three window frames made from PVC and steel. The carbon footprint of a PVC window frame with steel reinforcements is based on a verified Category 2 LCA study from SGS Search (2018) commissioned by VMRG and VKG. The carbon footprint of a PVC window frame with a steel core and of a PVC window frame with internal steel tubes are based on Category 3 data from the NMD (2016).

Only limited maintenance is reported in the verified LCA study. Based on their experience and expertise, Repair Care has indicated they expect more maintenance might be required to ensure the window frames will reach their 75 year lifetime. However, we will conform to the maintenance indicated in the verified LCA studies with which we compare the impact on climate change of window frame repair.

2.4 Functional unit

We investigate the repair or replacement of 'one fixed window frame, measuring 3,300 mm wide by 1,500 mm high'. These dimensions are in line with the functional unit of window frames according to the NMD before 2020 (after which EN17213 was published). All LCA studies of average window frames in the Netherlands that are publicly available at this moment, have been carried out using this functional unit. Glass is not included in the functional unit, in accordance with NL-SfB classification[4] and the Bepalingsmethode, although we do show the potential influence of glass on the carbon footprint in Section 3.3 (see Section 2.5 for more information).

The lifetime of the different window frames are:
- wooden window frames, softwood: 25 years (NBvT, 2016b);
- wooden window frames, hardwood: 75 years (NBvT, 2016c);
- aluminium window frames: 75 years ((SGS Search, 2018), (VMRG, 2020));
- PVC window frames: 75 years (SGS Search, 2018).

After a window frame is repaired its quality is as high as a new window frame, according to Repair Care. We therefore assume the same lifetime for both repaired and new window frames. In the results we make a distinction between the replacement of a softwood window frame (lifetime: 25 years) and a hardwood window frame (lifetime: 75 years).

2.5 System boundaries

The study scope is cradle-to-grave, meaning all steps from raw material extraction/ cultivation, material/product transport, Repair Care resin and window frame production, and disposal of the window frames at the end-of-life are included in the system boundaries (Table 1).

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[4] https://www.bimloket.nl/p/664/Over-NLSfB, The Bepalingsmethode applies NL-SfB classification for all building elements, such as window frames.

Table 1 - System boundaries of this study, according to the Bepalingsmethode and EN15804-A2

Product stage			Construction stage		Use stage					End-of-life stage				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Installation/ application	Use	Maintenance	Repair	Replacement	Refurbishment	Demolition	Transport	Recycling/energy	Final disposal	Benefits and loads from reuse, recovery, recycling potential
X	X	X	X	X	N.A.	X	X	X	N.A.	X	X	X	X	X

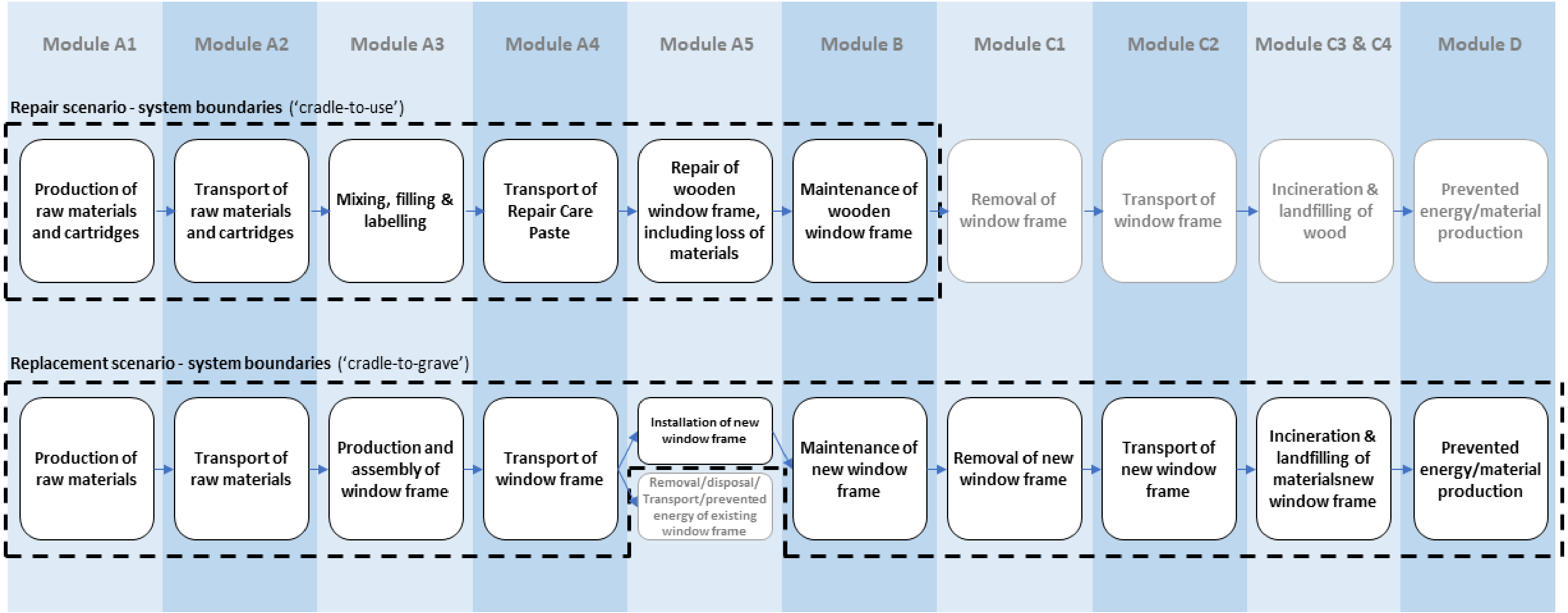
X: Included in LCA study.
N.A.: Not applicable.

As we include both repair and replacement options, two life cycle scenarios are included within the system boundaries:

1. **Repair**: preparation and repair of the existing damaged wooden window frame, maintenance during use, disposal after 25-75 years (depending on the material of the damaged window frame).
2. **Replacement**: removal and disposal of the existing damaged window frame, production and installation of a new window frame, maintenance during use, disposal after 25-75 years (depending on the material of the damaged window frame).

The life cycle stages within the system boundaries are presented in Figure 9 on the next page. We explain the system boundary choices below the figure.

Figure 9 - System boundaries of the repair & replacement scenarios (EN15804 modules indicated)*



* The omitted life cycle stages (Module C1-D in the repair scenario and part of Module A5 in the replacement scenario) are identical: they encompass the waste disposal of the damaged wooden window frame.

In the results, the carbon footprint of replacement scenarios is also provided with an approximation of the cradle-to-grave impact of the glass that is replaced. This is an expansion of the system boundaries, which is used to show the potential environmental benefit of the repair scenarios when glass is included. These results are only shown in Section 3.3 and fall out of the scope of the main results. The impact of glass is based on Category 3 data from the NMD (2022). The glass measures 3,190 x 1,410 mm per FU window frame.

2.5.1 Maintenance of repaired window frames

During the lifetime of wooden window frames, simple maintenance (paint repair) takes place every ten years. After 40 years, more extensive maintenance is carried out by removing all paint, sanding the window frames and reapplying new paint. The extensive maintenance only takes place for window frames of hard wood, as the lifetime of window frames of soft wood is shorter than 40 years (NBvT, 2016a, 2016b, 2016c):

- soft wood (25 year lifetime): two times simple maintenance;
- hard wood (75 years lifetime): seven times simple maintenance, one time extensive maintenance.

Based on their experience and expertise, Repair Care has indicated simple maintenance is required every seven years in the Netherlands. However, as the verified LCA study for wooden window frames has reported simple maintenance every ten years, we will assume maintenance every ten years as well.

2.5.2 Disposal of existing wooden window frame

The system boundary within this study therefore starts with the repair or removal of the damaged wooden window frame. The existing wooden window frame is disposed of in both scenarios: after 25-75 years in the repair scenario, or immediately in the replacement scenario. This will lead to a negative carbon footprint (a carbon sink), as wooden window frames are predominantly incinerated with energy recovery in the Netherlands, Germany and the United Kingdom. Incineration with energy recovery prevents energy production in power plants elsewhere. As the incineration of the existing wooden frame is identical for both scenarios, the in- or exclusion of this life cycle step in the results will not result in any difference in the comparison between the repair and replacement options. Including the negative result of the incineration of the existing wooden frame in the final results will make these results more difficult to read, however. To make the result easy to read, we have therefore chosen to leave the incineration of the existing wooden frame out of the final results.

Incineration of wooden window frames is common practice in the Netherlands and Germany. In the United Kingdom incineration is also the most likely waste disposal method, although here the possibility also exists the damaged wooden window frame might (partly) end up on a landfill. As no data is available about the likelihood the wooden window frames might end up on a landfill, we do not take this possibility into account. Landfilling the damaged wooden window frames would have a negative impact on the carbon footprint for both the repair and replacement scenarios. This would prevent the recovery of energy from the wood. Additionally, small amounts of methane would be released into the atmosphere due to the rotting processes.

2.6 Methodology

For window frames, specific LCA calculation rules are specified in *EN17213*[5]. At this moment, however, no LCA studies of average window frames that are carried out according to EN17213 are publicly available. We therefore cannot make a comparison in line with EN17213.

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[5] 17213:2020 Windows and doors - Environmental Product Declarations - Product category rules for windows and pedestrian doorsets.

Publicly available LCA studies of window frames that are available at this time have been carried out according to the Bepalingsmethode. To make a fair comparison possible, we therefore carry out the study according to the requirements and guidelines of the *Bepalingsmethode Milieuprestatie bouwwerken* (March 2022)[6]. The Bepalingsmethode is a uniform LCA method to calculate the environmental performance of building materials and structures in an unambiguous, verifiable and reproducible way. The method is based on *ISO 14040 – ISO 14044* and *EN 15804:2012+A2 (2019)*.

We carry out the LCA calculations using SimaPro 9.3.0.3 software, with background data from Carbon Minds 2021[7]. Where Carbon Minds is not sufficient, we use background data from ecoinvent 3.8 cut-off[8]. Carbon Minds is preferred for background data, as this database is specifically designed for chemicals and contains more recent data (0-5 years old) than ecoinvent (0-20 years old). We apply the cut-off criteria of the Bepalingsmethode (Section 2.6.3.6 and Annex IV), which means we model one life cycle until the 'end-of-waste' point, after which a new life cycle begins.

2.6.1 Biogenic CO_2

As mentioned in Section 2.1, some of the ingredients in the BIO FLEX™ ALLROUND and DRY FLEX® 4 contain organic matter. Organic matter takes up CO_2 from the atmosphere to grow, thereby (temporarily) storing the carbon. When the organic matter is incinerated, this stored biogenic carbon is released into the atmosphere again as CO_2. From material production to incineration, the net emission of CO_2 for organic matter is therefore zero. This net zero approach is in line with the Bepalingsmethode and EN15804.

During the incineration of the wooden window frame, Repair Care is incinerated as well. This causes an emission of carbon from the Repair Care products in the form of CO_2, which is partly fossil (contributing to climate change) and partly biogenic (net zero emissions). The exact carbon content is only known for BIO FLEX™ ALLROUND (component A + B combined)[9], though. For DRY FLEX® 4 and DRY FIX® UNI, the carbon content is unknown. It is therefore not possible to calculate the exact emission of fossil and biogenic carbon from the incineration of the wooden window frame.

We therefore have to estimate the benefit of using materials containing biogenic carbon. We do this by calculating the amount of biogenic carbon in each material and subtracting this biogenic carbon from their carbon footprint in SimaPro. The calculation of the biogenic content per material can be found in Annex D. We assume all Repair Care products are incinerated after use. Energy recovery during incineration is modelled in accordance with the Bepalingsmethode. We only consider the biogenic carbon of the Repair Care products, not of the window frames.

The results of Repair Care products are presented including and excluding the benefit of biogenic carbon.

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[6] www.milieudatabase.nl/en/environmental-performance/assessment-method/

[7] www.carbon-minds.com/lca-database-for-chemicals-and-plastics/

[8] www.ecoinvent.org/the-ecoinvent-database/

[9] TÜV Austria (2019). Biobased carbon certification BIOFLEX ALLROUND.

3 Results

In this chapter we present the carbon footprint of the Repair Care products in this study. In Section 3.1 we present the carbon footprint of repair care products per kg product. In this section we also go into the origin of the carbon footprint by looking at the contribution of different process steps. A contribution analysis of the components (with insight into the material contributions) is presented in Annex A. Additionally, a list with the carbon footprint per kg chemical used in Repair Care products is presented in Annex B.

In Section 3.2 we present the carbon footprint Repair Care products per repair type, which also includes application of the products. In Section 3.3 we compare the carbon footprints of the repair scenarios and the replacement scenarios. These scenarios also include the maintenance of the repaired or new window frames and the disposal of the new window frames. We additionally show the potential influence of glass on the carbon footprint in Section 3.3.

After we have discussed the results, we carry out a sensitivity analysis in Section 3.4, to investigate the influence of the most important assumptions and background data.

3.1 Carbon footprint Repair Care products (Module A1-A4)

The total carbon footprint per repair Care product is presented in Table 2 and Table 3 per kg product (component A + B). This footprint includes the production and transport of materials and packaging (tubes or bottles), transport to clients in the Netherlands (NL), Germany (DE) or the United Kingdom (UK) and losses that occur throughout the aforementioned steps. Repair-specific application of the resins and waste disposal of residue and packaging after application is not included.

Table 2 - Carbon footprint Repair Care products (component A + B) for different countries, per kg product, excluding application (Module A1-A4, *excluding* benefit biogenic carbon content)*

Repair Care Product	NL	DE	UK	Unit
DRY FLEX® 4	6.98	7.03	7.02	kg CO$_2$-eq./kg
BIO FLEX™ ALLROUND	6.69	6.75	6.74	kg CO$_2$-eq./kg
DRY FIX® UNI	7.24	7.29	7.28	kg CO$_2$-eq./kg

* The carbon footprint is presented with 2 decimals, to provide insight into the minor differences per country.

Table 3 - Carbon footprint Repair Care products (component A + B) for different countries, per kg product, excluding application (Module A1-A4, *including* benefit biogenic carbon content)*

Repair Care Product	NL	DE	UK	Unit
DRY FLEX® 4	6.67	6.72	6.71	kg CO$_2$-eq./kg
BIO FLEX™ ALLROUND	5.81	5.87	5.86	kg CO$_2$-eq./kg
DRY FIX® UNI	7.24	7.29	7.28	kg CO$_2$-eq./kg

* The carbon footprint is presented with 2 decimals, to provide insight into the minor difference per country.

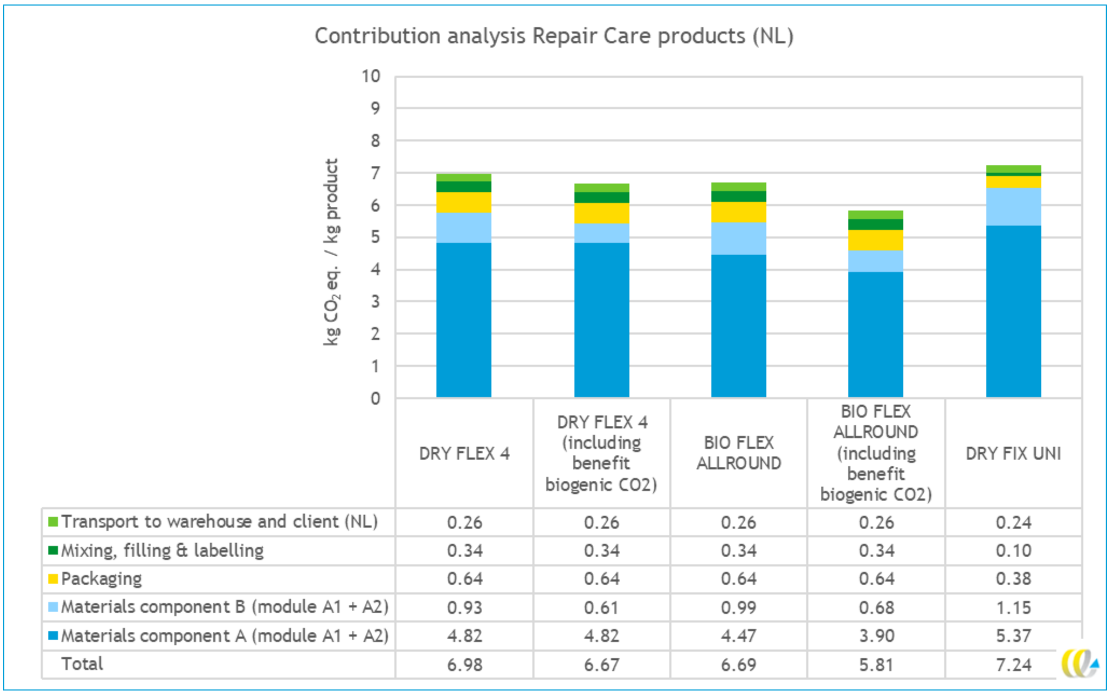
The carbon footprint of BIO FLEX™ ALLROUND is 4% lower than DRY FLEX® 4. When the benefit of biogenic carbon content in DRY FLEX® 4 and BIO FLEX™ ALLROUND is taken into account, the carbon footprint of DRY FLEX® 4 is 4.5% lower, while the carbon footprint of BIO FLEX™ ALLROUND is 13% lower. This means the carbon footprint of BIO FLEX™ ALLROUND is 12.5% lower than DRY FLEX® 4 when the benefit of biogenic content is taken into account. The carbon footprint of DRY FIX® UNI is identical with and without consideration of biogenic carbon content, as this product does not contain any organic material.

The variance of the carbon footprint of the products in the three countries is entirely caused by differences in transport distances from the factory in Taiwan to clients in the respective countries. The effect of these differences on the total carbon footprint are relatively small (<1%) and only visible when the results are presented with two decimals. As such, we only show the carbon footprint of the Repair Care products sold in the Netherlands in the following sections.

3.1.1 Contribution analysis Repair Care products, per kg product

The carbon footprint of the three Repair Care products before application is caused by the production and transport of materials for the resins/primer and packaging, mixing/filling/labelling and transport to the clients. The contribution of each of these process steps to the carbon footprint is presented in Figure 10 per kg product. A distinction is made between the carbon footprint including and excluding the benefit of biogenic carbon content.

Figure 10 - Contribution analysis Repair Care products (NL), per kg product, excluding application (Module A1-A4, excluding and including a benefit for biogenic carbon content)



	DRY FLEX 4	DRY FLEX 4 (including benefit biogenic CO2)	BIO FLEX ALLROUND	BIO FLEX ALLROUND (including benefit biogenic CO2)	DRY FIX UNI
🟩 Transport to warehouse and client (NL)	0.26	0.26	0.26	0.26	0.24
🟩 Mixing, filling & labelling	0.34	0.34	0.34	0.34	0.10
🟨 Packaging	0.64	0.64	0.64	0.64	0.38
🟦 Materials component B (module A1 + A2)	0.93	0.61	0.99	0.68	1.15
🟦 Materials component A (module A1 + A2)	4.82	4.82	4.47	3.90	5.37
Total	6.98	6.67	6.69	5.81	7.24

For all Repair Care products, more than half of the carbon footprint is caused by the production of component A (roughly 70% for the FLEX products and 75% for DRY FIX® UNI). Component B only contributes around 10-15% for the FLEX products and 15% for DRY FIX® UNI. The relatively low contribution of component B mainly has to do with the fact that less

component B is required for repairs (3A : 1B for FLEX, 2A : 1B for FIX). Additionally, the carbon footprint of component B is lower.
The contribution of packaging, mixing/filling/labelling and the transport to the warehouse are all relatively low. Packaging contributes about 10% for the FLEX products and 5% for DRY FIX® UNI. Mixing/filling/labelling contributes roughly 5% for the FLEX products and 1% for DRY FIX® UNI. Transport to the client contributes roughly 3-4% for all products.

3.2 Carbon footprint wooden window frame repair, Repair Care products only (Module A1-A5)

The carbon footprint of the Repair Care products can also be expressed per repair type. This carbon footprint also includes the application of the resins, which encompasses losses during application and due to residue in the containers. The losses, residue and empty containers are incinerated after use.

The carbon footprint of repairs carried out with DRY FLEX® 4 and BIO FLEX™ ALLROUND is presented in Table 4.

Table 4 - Carbon footprint Repair types (NL), per Repair Care product (Module A1-A5)

Repair type	Product	Carbon footprint (excluding benefit biogenic carbon content) (kg CO_2-eq./kg)	Carbon footprint (including benefit biogenic carbon content) (kg CO_2-eq./kg)	Unit
P2	DRY FLEX® 4	0.14	0.13	kg CO_2-eq./kg
	BIO FLEX™ ALLROUND	0.13	0.12	kg CO_2-eq./kg
C1/5	DRY FLEX® 4	0.43	0.41	kg CO_2-eq./kg
	BIO FLEX™ ALLROUND	0.41	0.37	kg CO_2-eq./kg
C2/25	DRY FLEX® 4	1.98	1.91	kg CO_2-eq./kg
	BIO FLEX™ ALLROUND	1.92	1.73	kg CO_2-eq./kg
C4/25	DRY FLEX® 4	3.11	3.01	kg CO_2-eq./kg
	BIO FLEX™ ALLROUND	3.01	2.71	kg CO_2-eq./kg

When the benefit of biogenic carbon content is taken into account, the carbon footprint of repairs carried out with DRY FLEX® 4 is 3.5% lower, while the carbon footprint of repairs carried out with BIO FLEX™ ALLROUND is 10% lower. This decrease in carbon footprint is entirely caused by the use of organic materials in both DRY FLEX® 4 and BIO FLEX™ ALLROUND.

Because a repair involves both the primer and the repair resins, the contribution of the repair resins (DRY FLEX® 4 AND DRY FLEX® ALLROUND) and primer (DRY FIX® UNI) can be found in Figure 11 and Figure 12 per repair type. Again a distinction is made between results excluding and including the benefit of biogenic carbon content.

Figure 11 - Contribution analysis repair types, per applied Repair Care product (Module A1-A5, *excluding* benefit biogenic carbon content)

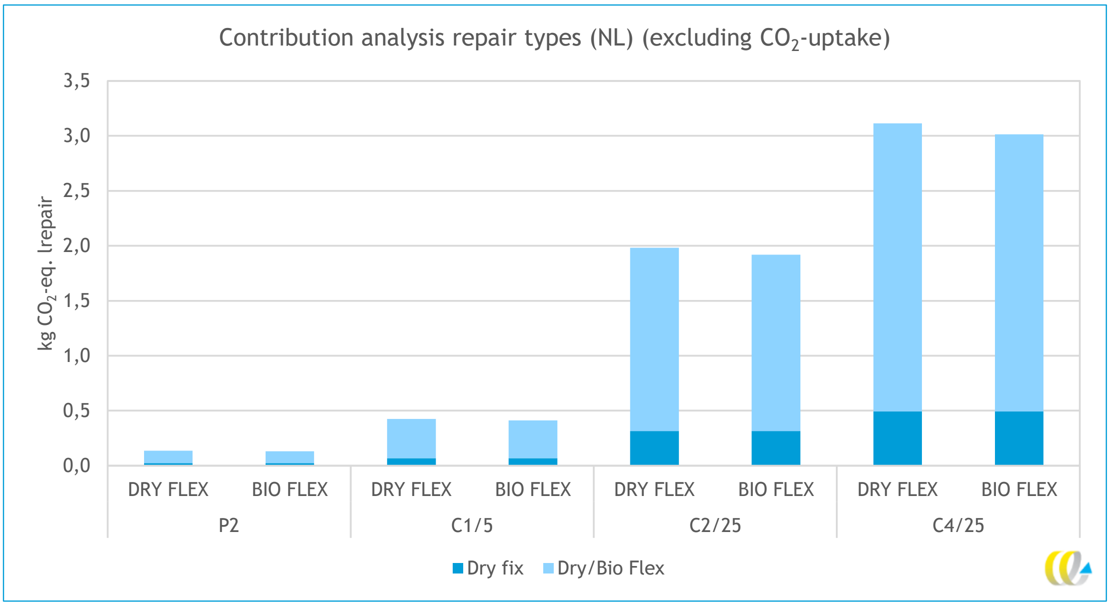
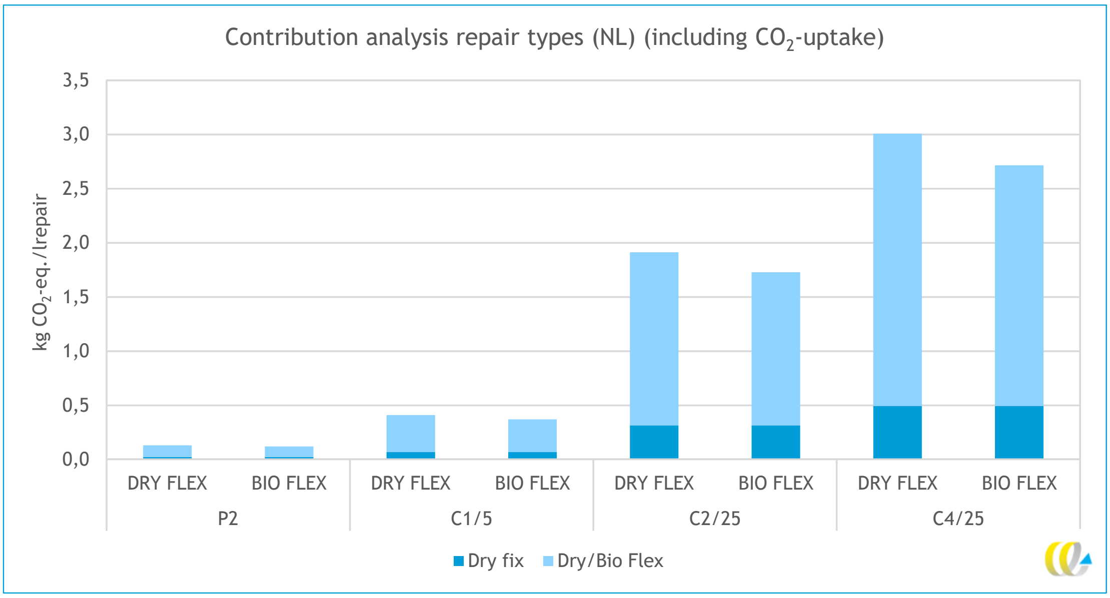


Figure 12 - Contribution analysis repair types, per applied Repair Care product (Module A1-A5, *including* benefit biogenic carbon content)



The carbon footprint increases with the severity of the repair from P2 to C4/25. The carbon footprint of repairs carried out with BIO FLEX™ ALLROUND is slightly lower (3%) than the carbon footprint of repairs carried out with DRY FLEX® 4. When the benefit of biogenic carbon content is taken into account, the carbon footprint of repairs with BIO FLEX™ ALLROUND is 10% lower. This difference might be associated with uncertainties in the background data, however, which we investigate further in Section 3.4.1. For all repairs (ex- and including the benefit of the biogenic carbon content), the repair resins contribute around 84% to the total carbon footprint per repair, while the remaining 16% can be attributed to DRY FIX® UNI.

3.3 Carbon footprint wooden window frame repair and replacement, entire lifecycle (Module A1-D)

To compare the repair and replacement scenarios for window frames we look at the Dutch situation, in line with the results in Section 3.2. For the repair scenario the entire lifecycle includes the production, transport and application of the Repair Care products, applying new paint to the repaired window frame and maintenance during the lifetime of the window frames. For the replacement scenario the entire lifecycle includes production, transport and installation of the new window frame, as well as maintenance and waste disposal of this new window frame.

During the comparison, we conform to the reported lifetime and maintenance reported in the verified LCA studies for wooden, PVC and aluminium window frames (see Section 2.5). Based on their experience and expertise, Repair Care has indicated the reported lifetimes for wooden window frames appear to be relatively high, while maintenance of both the wooden, PVC and aluminium window frames appear to be relatively low (see Section 2.3).

First we present the carbon footprint of the repair scenarios Section 3.3.1, after which we compare these repair scenarios with replacement scenarios in Section 3.3.2.

3.3.1 Carbon footprint of repair scenarios

The carbon footprint of repair scenarios is presented in Table 5 for a damaged window frame from hardwood (lifetime: 75 years) and Table 6 for a damaged window frame from softwood (lifetime: 25 years). As explained in Section 2.4, we take the lifetime of the repaired wooden window frame into account, which we assume is identical to the original lifetime of the window frame. This is 25 years for softwood and 75 years for hardwood. This also affects the maintenance, as explained in Section 2.5.

Table 5 - Carbon footprint of *hardwood* window frame repair, entire life cycle (Module A1-D, during 75 years, excluding waste disposal of original repaired wooden frame)

Repair type	Products	Carbon footprint (excluding benefit biogenic carbon content)*	Carbon footprint (including benefit biogenic carbon content)*	Unit
P2	DRY FLEX®	22.5	22.5	kg CO_2-eq./kg
	BIO FLEX	22.5	22.5	kg CO_2-eq./kg
C1/5	DRY FLEX®	22.8	22.8	kg CO_2-eq./kg
	BIO FLEX	22.8	22.8	kg CO_2-eq./kg
C2/25	DRY FLEX®	24.4	24.3	kg CO_2-eq./kg
	BIO FLEX	24.3	24.1	kg CO_2-eq./kg
C4/25	DRY FLEX®	25.6	25.5	kg CO_2-eq./kg
	BIO FLEX	25.5	25.2	kg CO_2-eq./kg

* The carbon footprint is presented with 1 decimal, to provide insight into the minor differences between products and including the benefit of biogenic carbon content.

Table 6 - Carbon footprint of wooden window frame repair, entire life cycle (Module A1-D, during 75 years, excluding waste disposal of original repaired wooden frame)

Repair type	Products	Carbon footprint (excluding benefit biogenic carbon content)*	Carbon footprint (including benefit biogenic carbon content)*	Unit
P2	DRY FLEX®	2.0	2.0	kg CO_2-eq./kg
	BIO FLEX	2.0	2.0	kg CO_2-eq./kg
C1/5	DRY FLEX®	2.3	2.3	kg CO_2-eq./kg
	BIO FLEX	2.3	2.2	kg CO_2-eq./kg
C2/25	DRY FLEX®	3.9	3.8	kg CO_2-eq./kg
	BIO FLEX	3.8	3.6	kg CO_2-eq./kg
C4/25	DRY FLEX®	5.0	4.9	kg CO_2-eq./kg
	BIO FLEX	5.0	4.7	kg CO_2-eq./kg

* The carbon footprint is presented with 1 decimal, to provide insight into the minor differences between products and including the benefit of biogenic carbon content.

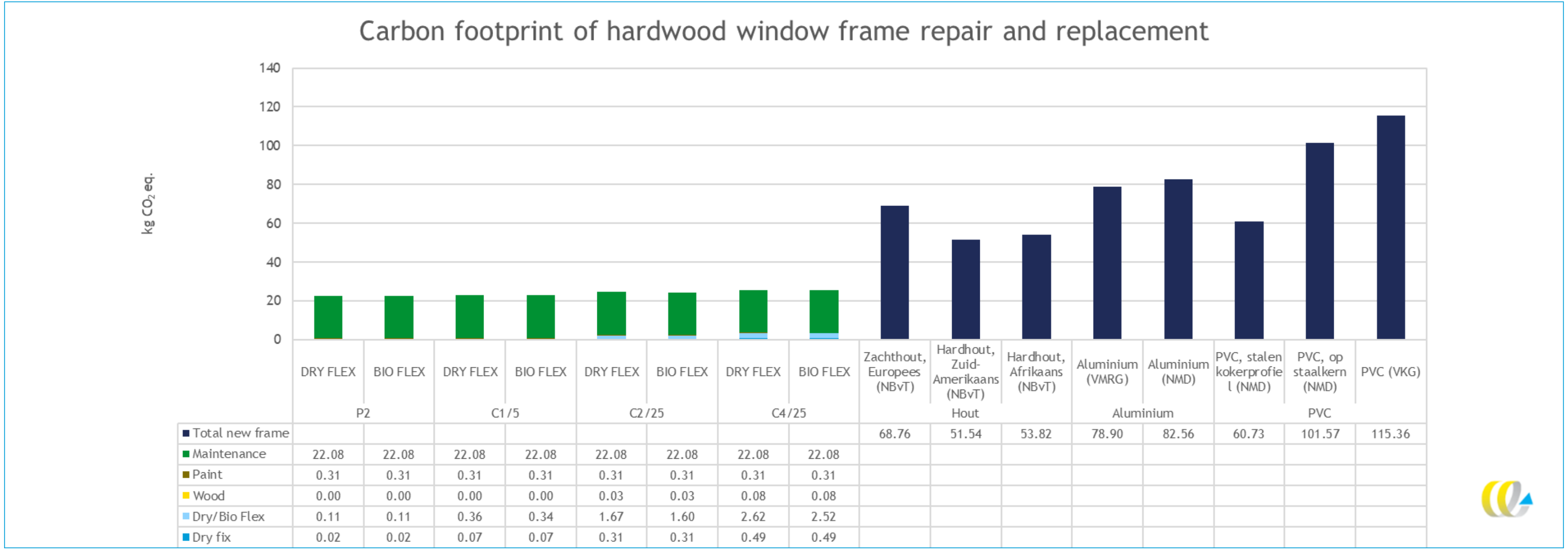
When taking into account the benefit of biogenic carbon content, the carbon footprint of repairs with DRY FLEX® are reduced with 0% (P2) to 2% (C4/25), while the carbon footprint of repairs with BIO FLEX are reduced with 0% (P2) to 5% (C4/25). The reduction increases with the severity of the repair, as more resin is applied.

3.3.2 Comparison between repair and replacement scenarios

The comparison between window repair and replacement is presented in Figure 13 for a damaged window frame from hardwood (lifetime: 75 years) and in Figure 14 for a damaged window frame from softwood (lifetime: 25 years). As this difference caused by the benefit of biogenic carbon content is only minor in comparison to the replacement scenarios, we present the comparison between the repair and replacement scenarios only with the results excluding the benefit of biogenic carbon content.

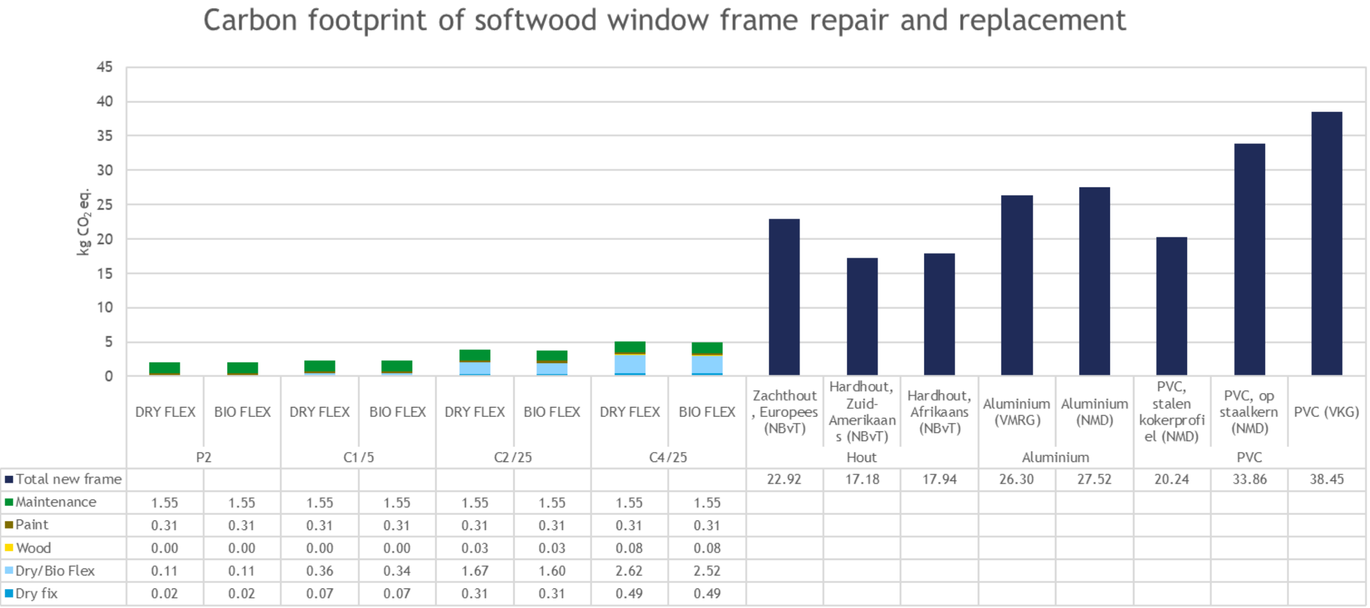
Because the glass within the window frames does not always have to be replaced in the repair scenarios (only when the glass is damaged or when it needs to be replaced with better insulating glass), this can be an additional environmental benefit of the repair scenarios. We therefore also present the results including the waste disposal of existing glass and the production and installation (Module A1 – D) of new glass in the replacement scenarios in Figure 15 and Figure 16, as an approximation of the potential influence of the glass. Other elements such as ventilation grills, adhesive and glazing bars are not included, as their carbon footprint is much smaller than the glass itself. We assume the glass is only replaced during the replacement of the window frame and does not need further replacement during the lifetime of the window frame.

Figure 13 - Carbon footprint of *hardwood* window frame repair and replacement, entire life cycle (Module A1-D, during 75 years, excluding waste disposal of original repaired/replaced wooden frame, *excluding* benefit biogenic carbon content)



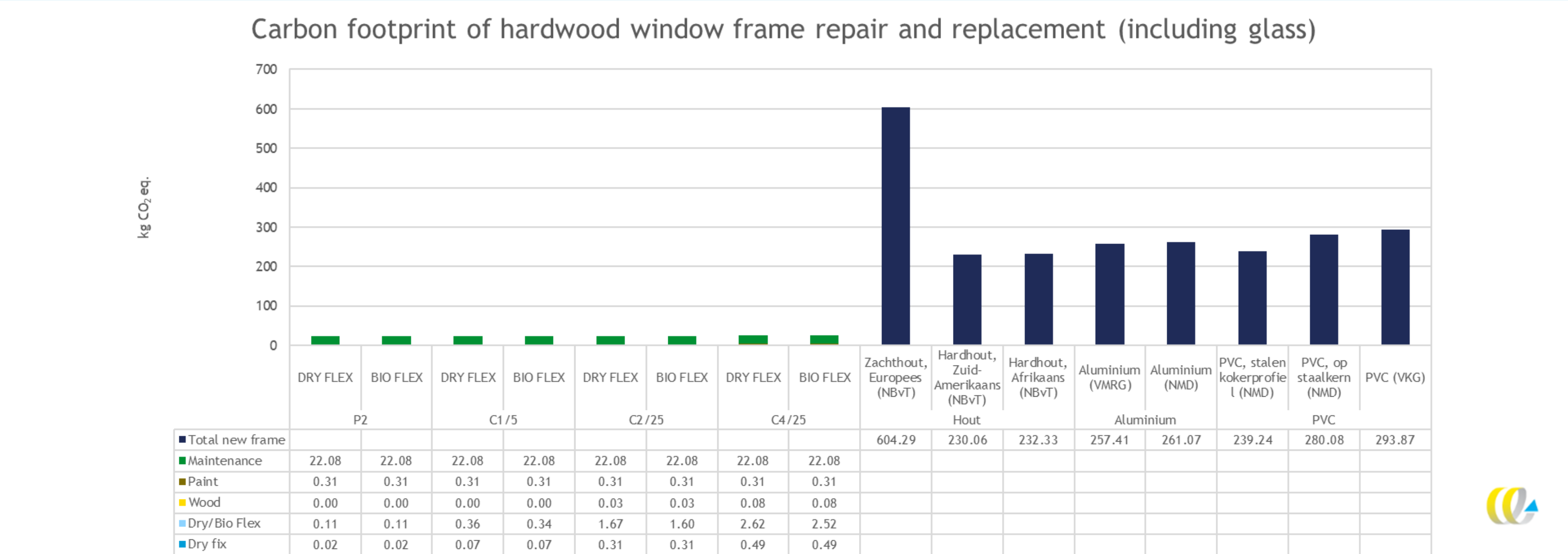
	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
	P2		C1/5		C2/25		C4/25		Hout			Aluminium		PVC		
■ Total new frame									68.76	51.54	53.82	78.90	82.56	60.73	101.57	115.36
■ Maintenance	22.08	22.08	22.08	22.08	22.08	22.08	22.08	22.08								
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31								
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08								
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52								
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49								

Figure 14 - Carbon footprint of *softwood* window frame repair and replacement, entire life cycle (Module A1-D, during 25 years, excluding waste disposal of original repaired/replaced wooden frame, *excluding* benefit biogenic carbon content)



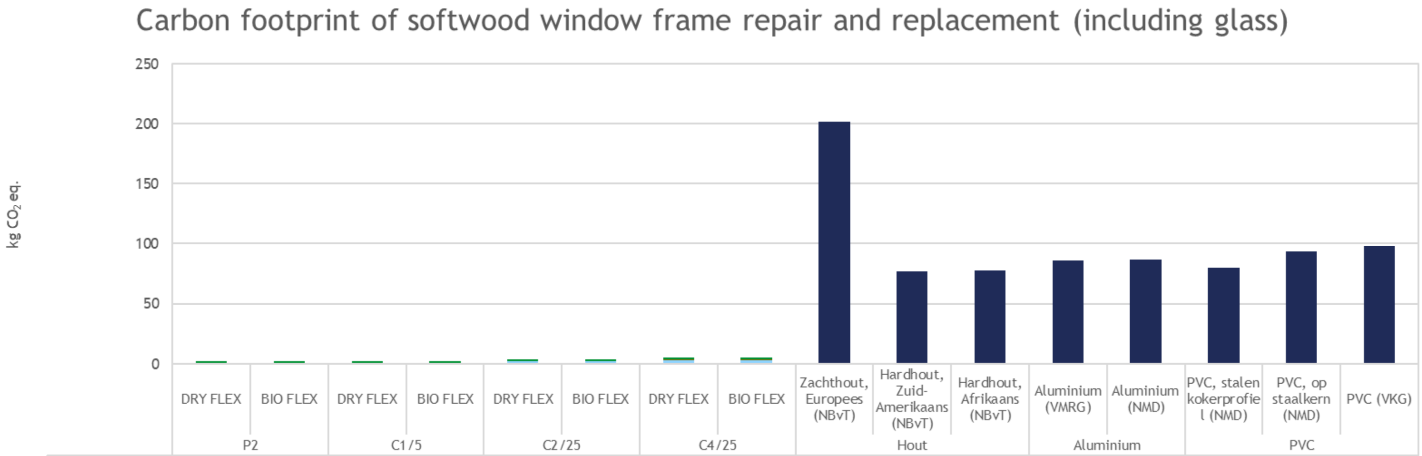
	P2		C1/5		C2/25		C4/25		Hout			Aluminium		PVC		
	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
■ Total new frame									22.92	17.18	17.94	26.30	27.52	20.24	33.86	38.45
■ Maintenance	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55								
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31								
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08								
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52								
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49								

Figure 15 - Carbon footprint of *hardwood* window frame repair and replacement, including *glass* in replacement scenario, entire life cycle (Module A1-D, during 75 years, excluding waste disposal of original repaired/replaced wooden frame, *excluding* benefit biogenic carbon content)



	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
	P2		C1/5		C2/25		C4/25		Hout			Aluminium		PVC		
■ Total new frame									604.29	230.06	232.33	257.41	261.07	239.24	280.08	293.87
■ Maintenance	22.08	22.08	22.08	22.08	22.08	22.08	22.08	22.08								
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31								
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08								
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52								
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49								

Figure 16 - Carbon footprint of *softwood* window frame repair and replacement, including *glass* in replacement scenario, entire life cycle (Module A1-D, during 25 years, excluding waste disposal of original repaired/replaced wooden frame, *excluding* benefit biogenic carbon content)



	P2		C1/5		C2/25		C4/25		Hout			Aluminium		PVC		
	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	DRY FLEX	BIO FLEX	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
■ Total new frame									201.43	76.69	77.44	85.80	87.02	79.75	93.36	97.96
■ Maintenance	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55								
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31								
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08								
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52								
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49								

When comparing the repair scenarios with the replacement scenarios, repairing the window frame results in a significantly lower carbon footprint in all cases. This is the case for both damaged window frames made from softwood and from hardwood. Both figures do not include the benefit of biogenic carbon content, which would entail a slightly decreased carbon footprint for all repair scenarios (0-5%).

The difference in the carbon footprint of the repair and replacement scenarios between Figure 13 and Figure 14 is caused by the differing lifetime of the window frames (25 or 75 years). For the repair scenarios more extensive maintenance is required during 75 years than 25 years (see Section 2.5). For the replacement scenarios we take the entire lifetime of the window frames into account, which means three window frames of softwood (lifetime of 25 years) are required compared to one window frame of hardwood, aluminium or PVC (lifetime of 75 years). Reversely, to compare to the window frame of softwood (lifetime 25 years) with the other window frames (lifetime 75 years), the carbon footprint of the window frames of hardwood, aluminium or PVC is divided by three, as they are only on 1/3rd of their lifetime after 25 years.

Even when comparing the most beneficial replacement option (replacement with a window frame from hardwood) with the least beneficial repair option (splicing repair, C4/25), the repair scenario has a lower carbon footprint. In fact, even when a damaged window would require multiple splicing repairs (which increases the carbon footprint of the Repair Care resins, not of the paint maintenance), the carbon footprint of the repair scenario would still be lower when the same lifetime is considered.

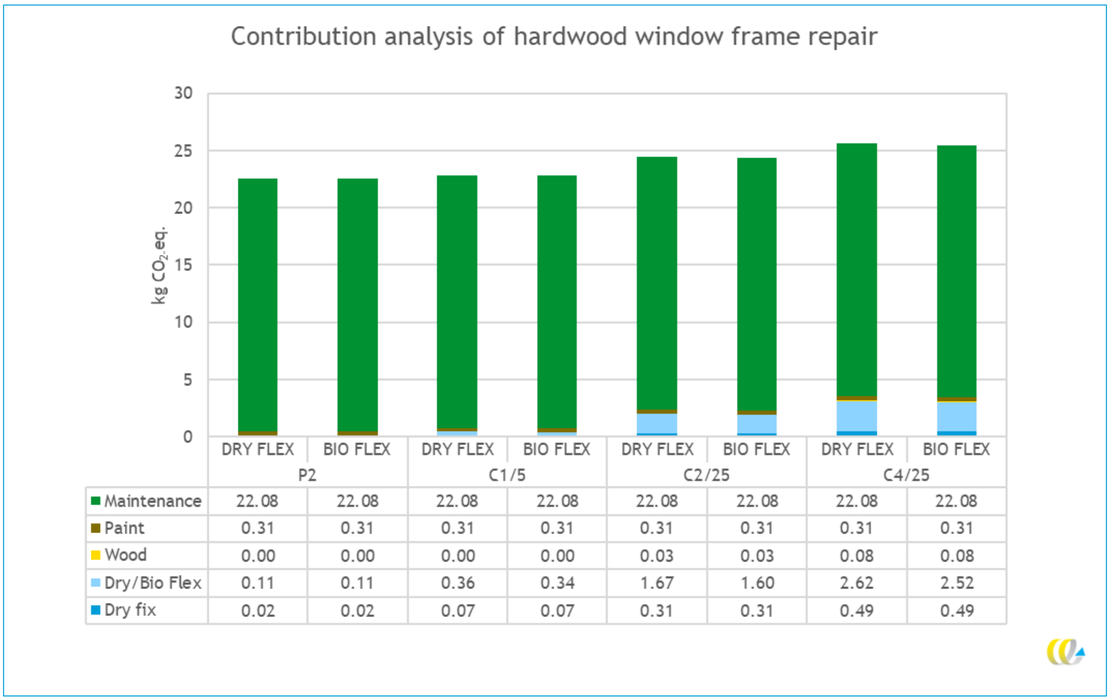
When we include the replacement of glass in the replacement scenarios as well, the difference between the repair and replacement scenarios increases even further, and quite dramatically. The carbon footprint of the replacement scenarios increases with a factor 1.5 to 3.5 for most window frames, and almost a factor 8 higher for new window frames of softwood. This increase is so dramatic, because the carbon footprint of the glass is higher than the carbon footprint of any of the window frames. This means the replacement of the glass alone results in a higher carbon footprint than the entire repair scenario. The carbon footprint of replacement with a softwood window frame with glass increases most radically to almost 8 times the carbon footprint of the window frame without glass. This is due to its relatively low lifetime of 25 years, which means both the window frame and the glass need to be replaced more often than with other window frames. As such, the carbon footprint of the softwood window frame is much higher.

3.3.3 Zooming in on the repair and replacement scenarios

For almost all repair scenarios most of the carbon footprint of the repairs is not caused by the Repair Care products, but by the maintenance of this window frame throughout its lifetime (Figure 17 and Figure 18). This is especially true when a hard wooden window frame (lifetime: 75 years) is repaired, as this window frame requires more extensive maintenance during its 75 year lifetime, according to the verified EPDs of window frame production (see Section 2.3). With window frame from softwood (lifetime: 25 years), the impact of the splicing repair is higher than maintenance, but lower for the other repair types.

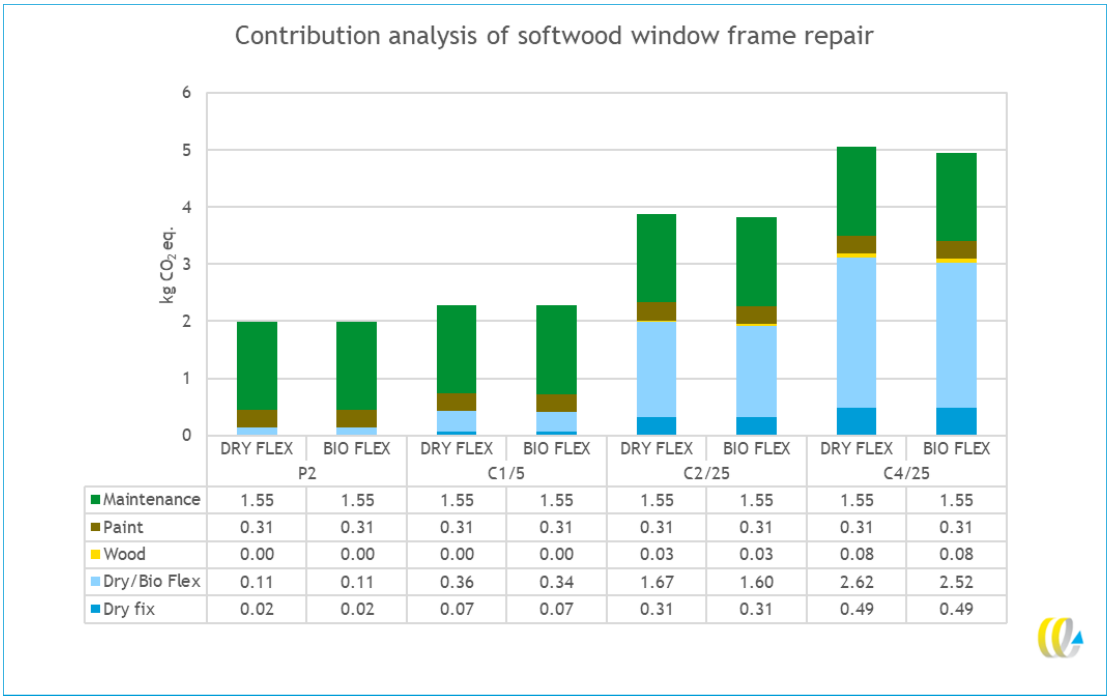
The paint and maintenance requirements do not change when more repairs are carried out simultaneously, as the window frame is painted over entirely to conceal the repair(s). This explains why even three splicing repair (C4/25) still results in a lower carbon footprint than replacement with a new window frame, as the required maintenance and paint do not change.

Figure 17 - Contribution analysis of *hardwood* window frame repair (entire lifecycle, during 75 years, excluding waste disposal of repaired wooden frame, *excluding* benefit biogenic carbon content)



	P2 DRY FLEX	P2 BIO FLEX	C1/5 DRY FLEX	C1/5 BIO FLEX	C2/25 DRY FLEX	C2/25 BIO FLEX	C4/25 DRY FLEX	C4/25 BIO FLEX
■ Maintenance	22.08	22.08	22.08	22.08	22.08	22.08	22.08	22.08
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49

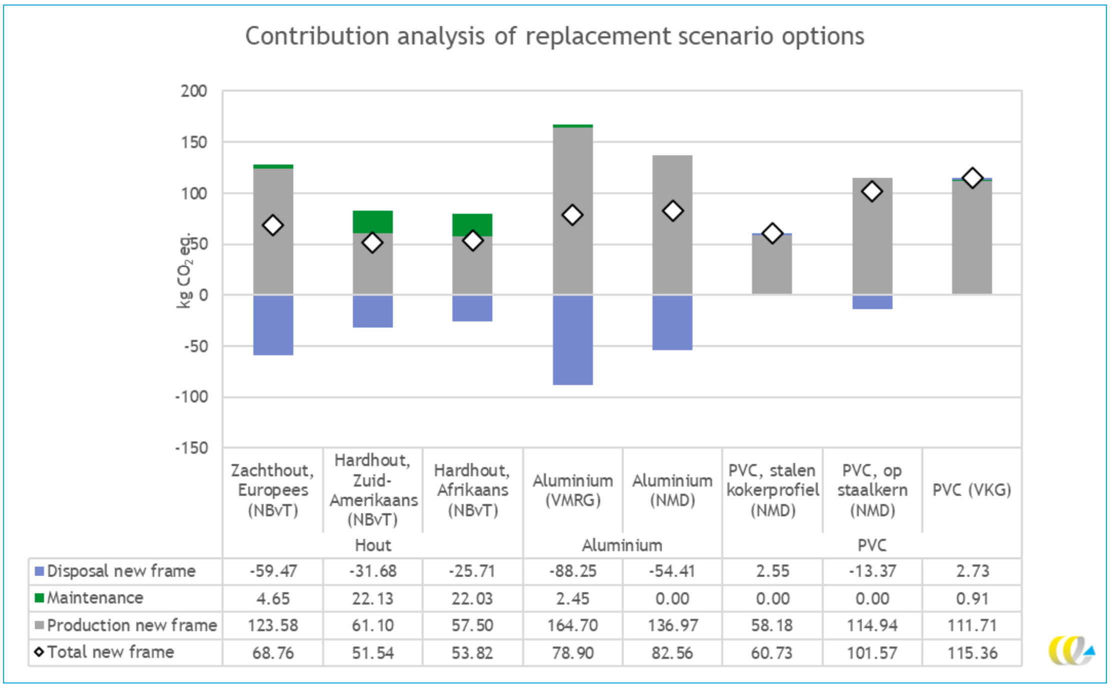
Figure 18 - Contribution analysis of *softwood* window frame repair (entire lifecycle, during 25 years, excluding waste disposal of repaired wooden frame, *excluding* benefit biogenic carbon content)



	P2 DRY FLEX	P2 BIO FLEX	C1/5 DRY FLEX	C1/5 BIO FLEX	C2/25 DRY FLEX	C2/25 BIO FLEX	C4/25 DRY FLEX	C4/25 BIO FLEX
■ Maintenance	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
■ Paint	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
■ Wood	0.00	0.00	0.00	0.00	0.03	0.03	0.08	0.08
■ Dry/Bio Flex	0.11	0.11	0.36	0.34	1.67	1.60	2.62	2.52
■ Dry fix	0.02	0.02	0.07	0.07	0.31	0.31	0.49	0.49

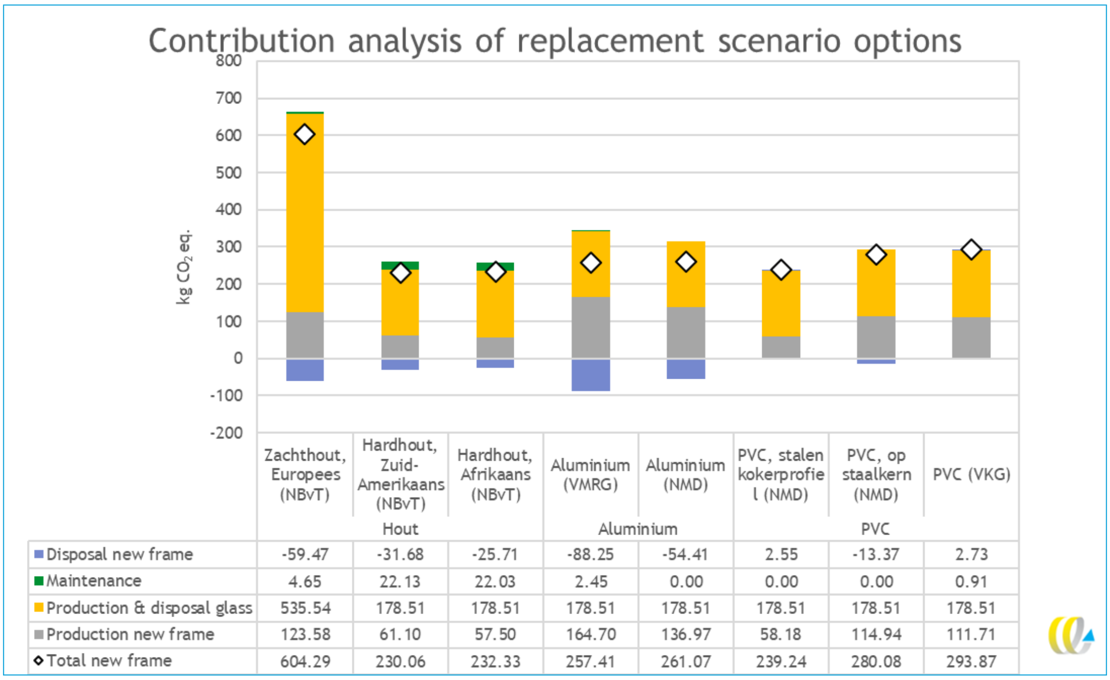
The contribution analysis of the replaced window frames is provided in Figure 19 (without glass) and Figure 20 (with glass) for a period of 75 years. Here we see that the maintenance makes up less than half the carbon footprint of the window frames from hardwood. This maintenance is identical to the maintenance of the repaired window frame.

Figure 19 - Contribution analysis of hardwood replacement scenario options (entire lifecycle, during 75 years, excluding waste disposal of replaced wooden frame), including total carbon footprint



	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
	Hout			Aluminium		PVC		
■ Disposal new frame	-59.47	-31.68	-25.71	-88.25	-54.41	2.55	-13.37	2.73
■ Maintenance	4.65	22.13	22.03	2.45	0.00	0.00	0.00	0.91
■ Production new frame	123.58	61.10	57.50	164.70	136.97	58.18	114.94	111.71
◇ Total new frame	68.76	51.54	53.82	78.90	82.56	60.73	101.57	115.36

Figure 20 - Contribution analysis of hardwood replacement scenario options, including *glass* (entire lifecycle, during 75 years, excluding waste disposal of replaced wooden frame), including total carbon footprint



	Zachthout, Europees (NBvT)	Hardhout, Zuid-Amerikaans (NBvT)	Hardhout, Afrikaans (NBvT)	Aluminium (VMRG)	Aluminium (NMD)	PVC, stalen kokerprofiel (NMD)	PVC, op staalkern (NMD)	PVC (VKG)
	Hout			Aluminium		PVC		
■ Disposal new frame	-59.47	-31.68	-25.71	-88.25	-54.41	2.55	-13.37	2.73
■ Maintenance	4.65	22.13	22.03	2.45	0.00	0.00	0.00	0.91
■ Production & disposal glass	535.54	178.51	178.51	178.51	178.51	178.51	178.51	178.51
■ Production new frame	123.58	61.10	57.50	164.70	136.97	58.18	114.94	111.71
◇ Total new frame	604.29	230.06	232.33	257.41	261.07	239.24	280.08	293.87

The disposal of most window frames results in a net negative carbon footprint. This is because the materials in the window frames are recycled (metals) and/or incinerated with energy recovery (wood), which prevents CO_2-eq. emissions in the future. This prevented emission is taken into account as a benefit in Module D[10], resulting in a negative carbon footprint.

3.4 Sensitivity analysis

This chapter is not available in the public version of this report.

3.5 Conclusion

In this LCA study we have investigated the carbon footprint of repair resins DRY FLEX® 4 and BIO FLEX™ ALLROUND, and impregnation agent DRY FIX® UNI. The repair of a damaged wooden window frame was investigated for four types of repairs, namely joint repair (P2), corner repair (C1/5), timber insert (C2/25) and splicing repair (C4/25). The carbon footprint of these repairs was compared to the replacement of the wooden window frame with new window frames made from softwood, hardwood, aluminium or PVC.

3.5.1 Production of Repair Care products & application in window frame repair

The carbon footprint or Repair Care products DRY FLEX® 4, BIO FLEX™ ALLROUND and DRY FIX® UNI differs only slightly for clients in the Netherlands, Germany and the United Kingdom (see Table 2). For all Repair Care products most of the carbon footprint can be attributed to the ingredients of the products, predominantly associated with component A. Component B contributes less to the total carbon footprint per kg, as less volume of this component is used per kg resin and because the carbon footprint of component B per kg component is lower. Packaging and transport contribute less than 10% each to the total carbon footprint of the Repair Care products. The carbon footprint of BIO FLEX™ ALLROUND per kg resin is 4% lower than DRY FLEX® 4. When the benefit of biogenic content in the resins is taken into account, the carbon footprint of BIO FLEX™ ALLROUND is 12.5% lower than DRY FLEX® 4 per kg resin.

The carbon footprint of repairs carried out with Repair Care products increases with the severity of the repair types. Joint repair (P2) is associated with the lowest carbon footprint, while splicing repair (C4/25) is associated with the highest carbon footprint (see Table 4). This carbon footprint is primarily associated with the repair resins DRY FLEX® 4 or BIO FLEX™ ALLROUND). DRY FIX® UNI contributes only 16% to the carbon footprint of these repairs, as it is applied in less volume than the repair resins. The carbon footprint of repairs carried out with BIO FLEX™ ALLROUND is 3.5% lower than repairs carried out with DRY FLEX® 4. When the benefit of biogenic content in the resins is taken into account, the carbon footprint of repairs with BIO FLEX™ ALLROUND is 10% lower than repairs with DRY FLEX® 4.

3.5.2 Comparison between repairing and replacing damaged wooden window frames

Repairing a damaged wooden window frame with Repair Care Resins (DRY FLEX® 4 or BIO FLEX™ ALLROUND) is associated with a significantly lower carbon footprint than

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[10] In Module D benefits from recycling and energy recovery are subtracted from the total carbon footprint (or detrimental effect due to loss of recycled material is added to the carbon footprint), according to the Bepalingsmethode and EN15804.

replacement of the damaged window frame (see Figure 13 and Figure 14). Even when multiple splicing repairs (C4/25) are carried out on one window frame, the carbon footprint of repair is still lower than when the damaged window frame is replaced with any of the new window frames.

The repair itself only has a limited influence on the total carbon footprint of the repair scenarios, because the carbon footprint of the repair scenarios is predominantly caused by the maintenance of the repaired window frames over their lifetime, rather than by the repair itself.

When the replacement of glass is taken into account for the replacement scenarios as well, the carbon footprint of replacement increases quite dramatically (see Figure 15 and Figure 16). For most replacement scenarios the carbon footprint increases 1.5 to 3.5 times, while the carbon footprint the repair scenario with window frames from softwood increases almost eight times. This makes the repair scenarios even more preferable, when the glass in the repaired window frames can remain in place.

3.5.3 Sensitivity analysis

This section is not available in the public version of this report.

3.5.4 Recommendations

This section is not available in the public version of this report.

4 Background data - Repair Care

This chapter is not available in the public version of this report.

5 References

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