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# Separate collection and recycling of PVC flooring installation residue in Sweden

A system assessment  
Deliverable in WP6, project  
CONSTRUCTIVATE

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# Summary

This report is a deliverable in work package six of the Constructivate project. The scope of this deliverable is to create awareness of the existence of the collection and recycling system for plastic flooring in Sweden, to assess its climate impact and to identify opportunities and barriers to increase the collection and recycling rate of this material.

Recycling of construction and demolition (C&D) waste represents a major untapped potential in Sweden. There already exist a few separate collection systems for some of the C&D waste fractions, but they are only used to a limited extent. An example is the national system for separate collection and recycling of material residue from installation of plastic flooring.

The system was originally developed by the Swedish company Tarkett in 1998, and then transformed into a system for all flooring manufacturers in the national Swedish Flooring Association, GBR. It is operated under the name GBR Golvåtervinning, but the actual administration and logistics is operated by Tarkett. The quantity of material collected through the system was 334 tons in 2018, but Tarkett estimates that around 1800 tons of such plastic residue is generated every year in Sweden. Material which is not collected through the system is probably sent to incineration plants for energy recovery.

The life cycle analysis conducted in this study indicates that within the study's system boundaries the difference in climate footprint between incinerating the material with energy recovery and recycling in Sweden is 2 tons CO<sub>2</sub>-eq/ ton PVC flooring.

The following opportunities and barriers for increased collection and recycling rates are discussed in the report:

- **Lack of awareness.** The main barrier for using the collection and recycling system is the lack of awareness of the system's existence and how this works. This is true for both some of the flooring installation companies and especially for the organisations that purchase the flooring installation services.
- **No requirements from purchasers.** Very few purchasers of plastic flooring installation services set requirements in tender documents for separate collection and recycling of the installation residue.
- **Engagement from all manufacturers and recycling solution for all the material.** Tarkett only recycles material from its own products today and this might also be a barrier to increase collection rates. Two of other manufacturers have started tacking back their own material from 2018. It is important to engage the other manufacturers as well to develop a recycling solution.
- **Standard practice within the industry.** Setting goals to reduce the amount of waste sent to energy recovery among different stakeholder in the industry can also contribute to increasing the collection rate through the system. Using the collection and recycling system should become the standard within the industry.
- **User-friendliness.** Even though the installing companies say the collection system works well for them, they still see potential for improving the user-friendliness of how the material is collected by employees during flooring installation.

# Sammanfattning

Denna rapport är en leverabel inom Constructivate-projektets sjätte arbetspaket. Denna leverabel omfattar medvetandegörandet av att det finns existerande insamlings- och återvinningssystem för plastgolv installationsspill i Sverige, samt att bedöma dess klimatpåverkan och att identifiera möjligheter och hinder för att öka insamling och återvinningsgraden för detta material.

Återvinning av bygg- och rivningsavfall utgör en stor outnyttjad potential i Sverige. Det finns redan återvinningssystem för några av fraktionerna, men de används endast i liten utsträckning. Ett exempel är det nationella systemet för separat insamling och återvinning av materialrester från installation av plastgolv.

Systemet utvecklades ursprungligen av det svenska företaget Tarkett AB år 1998, och omvandlades sedan till ett system åt alla golv tillverkare i Golvbranschen, GBR. Det drivs under namnet GBR Golvåtervinning, men den faktiska administrationen och logistiken sköts av Tarkett AB. Mängden material som samlades in genom systemet var 334 ton år 2018, men Tarkett uppskattar att cirka 1800 ton av sådana plastrester uppkommer varje år i Sverige. Material som inte samlas in via systemet skickas förmodligen till förbränningsanläggningar för energiåtervinning.

Livscykelanalysen som genomfördes inom denna studie indikerade att inom studiens systemgränser är skillnaden i klimatavtryck mellan förbränning av materialet med energiåtervinning och materialåtervinning i Sverige 2 ton CO<sub>2</sub>-ekv/ ton PVC-golv.

Följande möjligheter och hinder för ökade insamlings- och återvinningsgrader har identifierats och diskuteras i rapporten:

- **Brist på medvetenhet.** Det huvudsakliga hindret mot att använda insamlings- och återvinningssystemet är bristen på medvetenhet om systemets existens och hur det fungerar. Detta gäller både för golvinstallationsföretag och speciellt för de organisationer som köper golvinstallationstjänsterna.
- **Inga krav från köparna.** Mycket få köpare av plastgolvsinstallationstjänster ställer krav i anbudsdokument för separat insamling och återvinning av installationsresterna.
- **Engagemang från alla tillverkare och återvinningslösningar för allt material.** Tarkett återvinner endast material från sina egna produkter idag och detta kan också vara ett hinder mot att öka insamlingsgraderna. Två andra tillverkare har börjat ta tillbaka sina egna material från och med år 2018. Det är viktigt att engagera alla de andra tillverkarna och också att utveckla lösningar för återvinning av materialen från deras produkter.
- **Standardpraxis inom branschen.** Att sätta mål för att minska mängden avfall som skickas till energiåtervinning bland olika intressenter i branschen kan också bidra till att öka insamlingsgraden genom systemet. Användandet av insamlings- och återvinningssystemet borde bli till standard inom branschen.
- **Användarvänlighet.** Även fastän de installerande företagen säger att insamlingssystemet fungerar bra för dem, ser de fortfarande potential för förbättring av användarvänligheten av hur materialet samlas in av anställda under golvinstallationen.

# 1 Introduction

## 1.1 Background

This analysis is a deliverable in Work Package six of the Constructivate project, a four-year research project funded by the program Mistra Closing the Loop II. The main objective of Constructivate is to identify how to achieve a more resource efficient recycling of construction and demolition (C&D) waste. The ambition is not only to develop technology solutions but also to map the possibilities and barriers within this area.

Recycling of C&D waste represents a major untapped potential in Sweden. There already exist a few recycling systems for some of the C&D waste fractions, but they are only used to a small extent. Such a system is the one for separate collection and recycling of material residue from installation of plastic flooring.

In 2018, 25 percent of all flooring installed in Sweden was plastic flooring, the equivalent of approximately 6.4 million square meters (Swedish Flooring Association, 2019). Plastic flooring is usually installed in indoor spaces which require high durability (e.g. schools, hospitals) or in environments with high humidity (e.g. bathrooms). During the flooring installation process as much as 10 percent of the material can become installation residue (Swedish Flooring Association, 2019). The Swedish company Tarkett AB started separate collection and recycling of this material already in 1998. This practice was then extended to a national system for the members of the Swedish Flooring Association.<sup>1</sup> The system is still operated by the company Tarkett AB today and is focused on collecting residue from installing polyvinyl chloride (PVC) and polyolefin floorings.

As figure 1 illustrates, the quantity of material collected through the system has increased in recent years and in 2018 there were collected 334 tons. However, Tarkett estimates that around 1800 tons of such residue is generated every year (Pettersson, 2019). Interviews with different stakeholders for this analysis revealed that the material which is not collected through the system is probably sent to incineration plants for energy recovery.

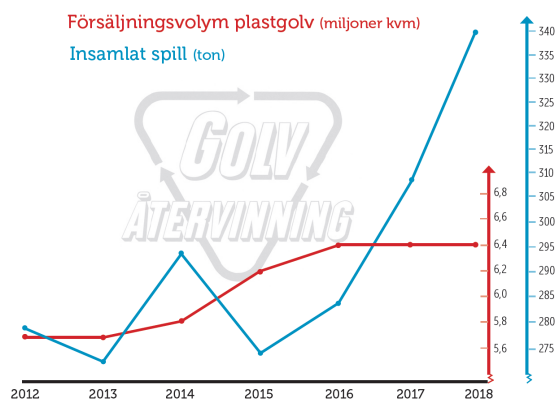


Figure 1. Plastic flooring sold in Sweden and the quantity of material residue collected from installation (Swedish Flooring Association, 2019)

<sup>1</sup> <https://www.golvbranschen.se/>

A total of 169 Swedish companies which install flooring are registered in the recycling system, 145 of them are members of the Swedish Flooring Association. The association has a total of 293 member companies which install flooring in Sweden. All the companies registered in the recycling system have their own profile in the association's database and can follow how much residual material they treat. Information is available even at project level.

The Swedish Flooring Association organised a competition in recent years with the objective to increase the amount of collected material through the system. The company which collected most residue material won a trip to the recycling plant in Ronneby. For example, the company which won the competition in 2016 collected 19 tons of residue material.

There is a major potential to increase the collection and recycling rate for residue plastic flooring in Sweden and, as shown later in the report, to reduce the environmental impact from today's treatment through energy recovery.

## 1.2 Scope and objective

This report is a deliverable in work package six of the Constructivate project. The scope of this deliverable is to create awareness of the existence of the collection and recycling system for PVC plastic flooring in Sweden and of the potential to increase the recycling rate of this material.

The objective of the report is three-fold:

- a. Describe how the collection and recycling system works;
- b. Assess the environmental impact of the current recycling rate for PVC flooring residue and compare it to a scenario where 100 percent of the residue flooring is collected for recycling;
- c. Map the opportunities and barriers for increasing the collection rate in Sweden.

## 1.3 Methodology

The methodology for the analysis in this report is based on the following three elements:

- a. Study visit at the recycling plant in Ronneby in Southern Sweden operated by the company Tarkett AB;
- b. Life cycle analysis (LCA);
- c. Interviews with companies working with flooring installation, as well as with private and public purchasers of such services.

Following the three methods are described into more detail.

### 1.3.1 Study visit

The project team from IVL visited in March 2019 the recycling plant located in Ronneby, Sweden. The plant is owned and operated by the company Tarkett AB. The visit enabled the project team to better understand how the system is operated, what type of materials are collected, how they are separated, granulated and used in the manufacturing process.



The recycling plant is co-located with one of the manufacturing plants that Tarkett owns, therefore the distance between sorting, granulation and manufacturing is small. Around 500 people work at the Tarkett's different plants in Ronneby.

During the visit, data was collected for the recycling process for the year 2018. These data are presented in chapter 2 and 3 of this report.

## 1.3.2 Interviews

Eight stakeholders accepted to participate in an interview or to provide information through e-mail. This data collection process unfolded in the period March-May 2019. The stakeholders represented the following groups:

- d. four companies which install flooring in different parts of Sweden (12 companies were contacted in total);
- e. four public and private organisations that purchase such services (10 such stakeholders were contacted in total)<sup>2</sup>.

## 1.3.3 Life cycle assessment

A life cycle assessment was conducted as well on the collection and recycling system for PVC flooring in Sweden.

Life cycle assessments (LCA) investigate the environmental impacts related to a product or a system during its whole life cycle. This includes evaluating energy and resource consumption as well as emissions, from all life cycle stages including; material production, manufacturing, use and maintenance, and end-of-life. A schematic overview of a life cycle is shown in Figure 2.

LCA is a widely used and accepted method for studies of environmental performance of various products and systems, for more details on how an LCA is performed and what parts it contains, see Appendix B.

The LCA in this report is performed in accordance with ISO 14040:2006 and ISO 14044:2006 standards (see figure 2).

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<sup>2</sup> See Appendix A for the list of stakeholders which provided input in the analysis.

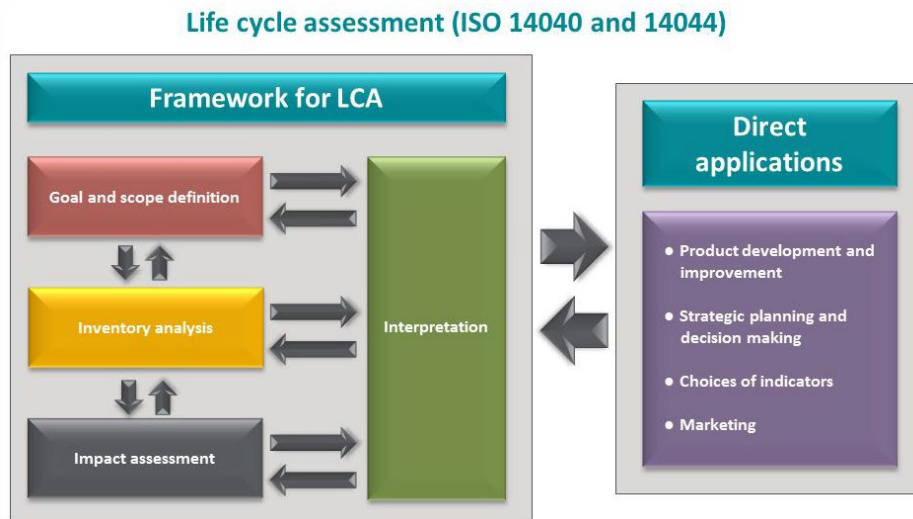


Figure 2. Illustration of the LCA system

## 1.4 Limitations

The report only focuses on separate collection and recycling of pre-consumer PVC flooring residue generated during the installation process in Sweden.

However, it should be mentioned that Tarkett also developed a new technology which is expected to enable the recycling of post-consumer flooring waste. This technology is under testing now. The technology removes glue and impurities in a washing process. This type of recycling is excluded from this study.

Tarkett collects and recycles in the Ronneby plant installation flooring residue from its own products also from Denmark, Norway, Finland, Northern Germany and parts of Poland. This material is also excluded from this study. Only material collected in Sweden is included in the analysis.

## 1.5 Structure of the report

The report has three main parts. The first part is a description of how the system is operated today by the company Tarkett AB. Every step from collection of the residue flooring on construction/renovation sites to recycling are described.

The second part of the report presents the life cycle assessment implemented on two different scenarios 1) the present scenario which is based on collection and recycling rates from 2018 and 2) a future scenario based on 100 percent collection rate.

The third part of the report presents the results from interviews with representatives of flooring installation companies and organisations that purchase such services. The identified main barriers and opportunities for increasing the collection rate and recycling of flooring residue are presented. The three main parts of the report are followed by the conclusions.

## 2 Description of the system for collection and recycling of residue plastic flooring

The recycling system for residual plastic flooring is operated by Tarkett AB, but eight other manufacturers that sell plastic flooring on the Swedish market are members as well. These manufactures are Altro Nordic AB, Amtico International AB, Bolon AB, AB Gustaf Kähr, Falck Design AB, Forbo Flooring AB, Gerflor Scandinavia A/S and Unilin Nordic AB. Flooring residue from all these nine manufactures can be collected through the system. The system is focused on collecting residue from installing PVC and polyolefin floorings. Currently, the system only collects pre-consumer plastic flooring waste, as the material is relatively clean.

All members of the Swedish Flooring Association, most of them companies which install flooring, can use the collection system free of charge for the management of flooring residue they produce. Companies which are not members in the association can use the collection system by paying a fee of 2 500 SEK per year (Swedish Flooring Association, 2019). This includes collection of the residue from the construction/renovation site and transport to the recycling plant in Ronneby.

Even though Tarkett also collects residue originating from flooring manufactured by the other eight companies, it only recycles material from its own products back into production. Starting from 2018, Tarkett sends installation residue from plastic flooring manufactured by Altro Nordic AB and Forbo Flooring AB back to the two companies. Residue originating from products of the the other six manufacturers is sent to incineration with energy recovery in Sweden. The amount of material collected through the system but sent to incineration is relatively low as almost 80 percent of the total flooring residue collected annually comes from Tarkett products (Risendal, 2019 ).

The Swedish Flooring Association and Tarkett have initiated discussions with all the manufacturers to assess the possibility for all of them to take back the material for recycling. All the other manufacturers are foreign-owned companies and production is located outside Sweden. It is a challenge to develop logistics models to take back the material or to invest in a joint recycling solution in Sweden as the quantities of material from the other manufacturers collected through the system are currently low (Adnerfall, 2018).

Figure 3 bellow illustrates the steps in the collection and recycling of the PVC flooring residue from collection on the construction/renovation site to granulation in the Tarkett plant in Ronneby. The following sections in the report describe the steps into more detail.



Figure 3 Steps in the collection system for PVC flooring installation residue (source: The Swedish Flooring Association)

## 2.1 On the construction/renovation site

Each company that installs flooring and wants to start to separately collect installation residue receives a bin the size of a euro pallet. The company also receives transparent bags marked with the names of all the different flooring manufacturers, as shown in figure 4. Each transparent bag must contain flooring residue from only one manufacturer and should be marked accordingly with a black resistant marker in the box next to the name of the specific manufacturer. The bags containing residual material can be then stored together in the same bin as shown in figure 5. Usually, each bin contains between 200-300 kg of installation flooring residue when is collected through the system (Pettersson, 2019). Figure 5 also represents an example of correct collection of the residue waste in different plastic bags. If the residue flooring is collected correctly – material from only one manufacturer per bag – and marked accordingly, it is much easier for the plant employees to sort the materials at the plant.

Tarkett has also developed a big bag for collection of flooring residue which targets larger construction projects. The collection process works the same way as for the bins but only Tarkett residue can be collected through big bags for now. Tarkett and the Swedish Flooring Association are assessing the possibility to collect materials from the other manufactures though big bags, as this is a more cost-efficient collection method.



Figure 4. Collection bag for plastic flooring residue with the names of all the manufacturers



Figure 5. Several bags containing residue from different manufacturers can be stored in the same bin.

Other waste objects should not be thrown into the bags or the bins. Especially sharp or hazardous objects. This is because once the material is transported at the plant in Ronneby, the bags and bins are opened and unloaded manually by plant employees. Sharp and dangerous objects can therefore injure the employees. Figure 6 illustrates different objects which have been found together with residue flooring in the bags and bins at the Tarkett plant.



Figure 6. Other objects thrown into the bins and bags intended for the collection of residual flooring.

## 2.2 Sorting at the plant in Ronneby

Each bin gets a unique number linked to the company which collected the material. At the plant in Ronneby the material is manually sorted according to the different manufacturers, as illustrated in Figure 7.



Figure 7. Sorting of plastic flooring residue according to manufacturer

The Swedish Flooring Association developed a digital database which allows those who submit residue materials through the collection system to follow how much residue they produce and collect each year.

Tarkett only recycles residue from its own products back into production of new flooring in Ronneby. The reason for this is the known composition of the material. The flooring composition from other manufactures is unknown to Tarkett as the companies do not share this information between themselves due to market competition.

In 2018, a total of 334 tons of residue plastic flooring was collected through the system by Tarkett. Out of that, 265.5 tons represented residue from Tarkett products, 40 tons came from products manufactured by Forbo Flooring and two tons from products manufactured by Altro Nordic. The rest of 26.5 tons represented residue flooring from all the other six manufacturers together (Pettersson, 2019). Residue material from Altro Nordic and Forbo Flooring was sent back to the two manufactures. For example, in 2018 Forbo Flooring started sending the material to its manufacturing plant in Coevorden, The Netherlands for further sorting and recycling (Rothén, 2019). It is unclear what Altro Nordic does with the material.

The rest of 26.5 tons representing a mix of materials from the other six manufacturers were sent to incineration with energy recovery.

## 2.3 Recycling

Out of the 265.5 tons of residue flooring collected in 2018 from Tarkett products, 223 tons were recycled into new products while the rest of 42.5 were sent to energy recovery. It was not possible to recycle the entire quantity due to different impurities, such as glue, which might affect the quality of the recycled material. 99 percent of Tarkett residue flooring which is recycled is made of PVC material.

The 223 tons which do not contained impurities entered the granulation process. The granulate is shown in figure 8.



Figure 8. PVC granulate to be recycled into new Tarkett flooring in Ronneby

Each batch with granulate contains material with slightly different compositions, qualities and colours. Due to this, each batch with granulate is mixed at the plant and a sample is then sent to the on-site laboratory for tests. Each batch is marked, registered in a database and stored. The computer in the laboratory indicates how much raw material, colour, plasticizer, etc. needs to be added to each batch to reach the quality and colour desired in the new products. This process is also the reason why Tarkett does not recycle material from other flooring manufacturers directly into its own production. With no knowledge about the different products from other manufacturers, it is too complex to identify all the ingredients in every granulate batch.

The average percentage of recycled material in Tarkett products is 23 percent, but this includes production waste as well not only installation residue. (Pettersson, 2019).

### 3 Environmental impact assessment

An LCA was performed on the collection and recycling system based on data from 2018. The results were compared to a future scenario where the entire quantity of generated residual PVC flooring in Sweden is collected through the system operated by Tarkett and not sent to incineration plants. The results of the LCA are presented in this chapter.



## 3.1 Goal and scope of the LCA

A clearly defined goal and scope are important to fully understand the LCA and the results. Together with the functional unit - a reference unit by which the inputs and outputs of the LCA should be scaled - the scope is what defines the circumstances under which the LCA results are valid.

The goal of the LCA was to identify the environmental impact measured in Global Warming Potential (GWP) with the unit of 'kg CO<sub>2</sub>-eq' in two different scenarios. The study compared the GWP of the present rate of collection and recycling for flooring residue with a potential future collection rate of 100 percent.

A well-defined scope is required according to the ISO standard and will clarify the boundaries under which the conclusions from the LCA are valid. The presentation in this section will give the reader a basic grasp of the scope, i.e. what system boundaries have been applied and what functional unit has been used.

### 3.1.1 Functional unit

A functional unit is used to relate the result to a fixed factor, to enable comparison of different cases based on the prerequisites of a certain function. This is important both when comparing results, but also important to understand in what cases the LCA results are valid as the results showing the environmental impacts are given regarding this function.

The desired function is analysis of treatment of the residue PVC flooring generated in Sweden in one year. The study includes a comparison of the environmental performance of the present case and future potential case.

*Chosen functional unit: Total amount of PVC residue flooring generated in Sweden for one year.*

### 3.1.2 Studied system

The studied system is the residue PVC flooring end-of-life treatment system in Sweden. It involves two waste management methods: energy recovery through incineration and recycling. Landfilling is not included since landfilling of this material is very low in Sweden.

The flow chart illustrated in Figure 9 shows the system boundary of the studied system. It is a gate-to-grave study which means the starting point of analysis is after flooring installation phase and the end is the final waste treatment. It involves several transportation steps and processes as listed below:

- **Recycling part:** In this part the material is collected from the construction/renovation site and transported to the recycling plant. During recycling process, electricity is used for the granulation machines. The share of the material which cannot be recycled will be sent to an incineration plant. The final product from the granulation process is the granulate material which is sent to the manufacturing step.

- Incineration part: Currently, energy recovery from residue flooring is the dominant waste treatment method in Sweden. Electricity and heat are produced during the incineration of this material.
- Collection and transportation of the material to other manufacturers: Two other plastic flooring manufacturers have asked Tarkett to send the residual material which is collected through the collection system back to them.

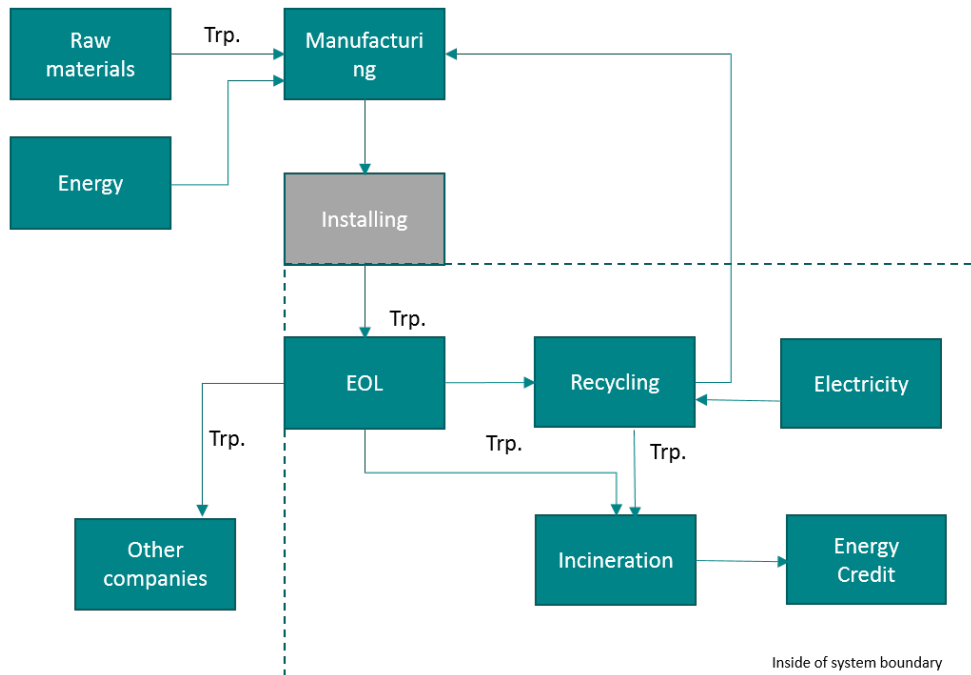


Figure 9. Flow chart of the residue flooring End-Of-Life (EOL) system. Inside of the dash board is the system boundary for this LCA study.

Tarkett estimates that there are around 1800 tons of residue flooring generated in Sweden per year while only around 334 tonnes have been collected in 2018. Figure 10 below illustrates the mass balance of the collection and recycling system based on data for 2018. After collection, the material is transported to the recycling plant in Ronneby. After sorting and separation, 42 tons of residue produced from products manufactured by Altro and Forbo were sent back to the two companies. From the remaining amount, 26.5 tons of material originating from other manufacturers' products were sent to energy recovery. From the remaining 265.5 tons, 223 tons could be recycled back into PVC flooring production at Tarkett's plant. The rest of 42.5 tons included different types of impurities which would have impaired recycling and were sent to energy recovery.

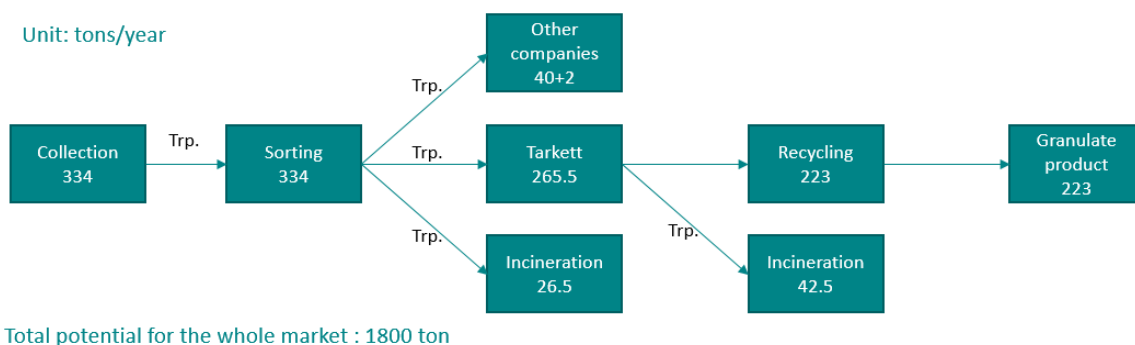


Figure 10. The mass balance chart of flooring recycling system. The value in each box indicates the collection amount of the system in 2018 (considered in this analysis ‘present situation’).

### 3.1.3 System boundaries, limitations and key assumptions

The residue flooring collection system is in Sweden. The studied geographical system boundary is also focused on Swedish market. Included within the system boundaries are transportation from construction sites to recycling plant and incineration plant, energy use for recycling processes, and environmental impacts from the incineration step. The granulated product is sent to the manufacturing step where it can fulfil almost the same function as virgin material. Thus, it contributes to avoiding emissions from the production of virgin PVC and this is also considered in the analysis.

VinylPlus states in its report on PVC recycling technologies that the PVC industry ensures that the quality and durability of products with recycled materials are the same as that of new PVC polymers. The material can be recycled more than eight times which makes PVC very sustainable with a life time of hundreds of years ( VinylPlus , 2013). The use of recycled PVC materials in the production of new flooring contributes to avoiding environmental impact from producing new virgin PVC material. This avoided environmental impact is considered in the LCA analysis and credit is given to the recycled material for this. It is difficult to calculate the value of such credit in the LCA analysis. In this study it was assumed that the recycled material keeps 85 percent of the value of the virgin material and this is calculated as credit in the analysis.

### 3.1.4 Selected impact category

The selected impact category for this study is global warming potential. The results are expressed in “kg CO2 equivalent”. Characterisation factors from CML 2001 were used.

Table 1. Environmental impact categories

Impact category	Category indicator	Reference
Global warming potential (GWP)	kg CO2 equivalents	CML2001 - Jan. 2016

## 3.2 Data collection

This section gives a brief overview of the data collection performed for this LCA. First the material composition of the studied product was researched. The subsection about site specific process data gives an overview of the process data specifically collected in this project, while the generic process data subsection lists what process data were taken from a generic database.

### 3.2.1 Recycling system for residue flooring

The life cycle assessment is focusing on the End-Of-Life system (EOL). The hot spot is the residue flooring collection and recycling. Two scenarios are studied, and both assume that the total generated amount of residual plastic flooring in Sweden in one year is 1800 tons:

- **Present scenario:** the present scenario is based on the collection rate in Sweden in 2018 when around 18 percent of residue flooring has been collected through the system while the rest is assumed to have been sent to incineration with energy recovery;
- **Future scenario:** the future scenario is set to have 100 percent collection rate of the material through the system.

In the case of both scenarios, around 17 percent of total collected quantity through the system cannot be recycled because of different impurities collected together with the material. Considering this, even in the case of the future scenario with 100 percent collection rate around 300 tons of material are considered as being sent to incineration in the study.

The overview of the two scenarios is presented in Table 2. For the present scenario, data were provided by Tarkett company. Transportation data were calculated based on an average distance.

**Table 2. End-Of-Life treatment for the two scenarios. Data presented for each life cycle stage.**

Life cycle stage	Description	Unit	Present scenario	Future scenario (100% collection)
<b>Total amount</b>	<b>Total generated residue flooring in Sweden</b>	<b>tons/year</b>	<b>1 800</b>	<b>1 800</b>
<b>Collected</b>	<b>Total collected amount</b>	<b>tons/year</b>	<b>334</b>	<b>1 800</b>
Recycling	Recycled amount	tons/year	223	1 500
Energy recovery	Incinerated amount (collected part)	tons/year	69	300
/	Sent back to other companies outside Sweden <sup>3</sup>	tons/year	42	0
<b>Uncollected (through this system)</b>	<b>Uncollected flooring residue (considered as energy recovery through incineration)</b>	<b>tons/year</b>	<b>1 466</b>	<b>0</b>
<b>Transport</b>	Construction/renovation site to recycling plant	km	300	300

<sup>3</sup> 42 tons/year residue flooring are sent back to two other companies. The impacts from this part are out of the studied system boundaries.

	Construction site to incineration plant	km	100	/
	Recycling plant to incineration plant	km	100	100

## 3.2.2 Production and process data

The scope of the LCA includes residue flooring collection, recycling and incineration with energy recovery. The environmental impact of these steps is analysed to compare the two scenarios. The flooring manufacturing step is outside of system boundary, while raw materials which are used to produce PVC floorings are included in the study since the impacts from upstream materials influence the value of recycled product (the credit given to the recycled material for contributing to avoiding emissions from production of virgin material).

### 3.2.2.1 Specific data from the recycling plant

Recycling data was provided by Tarkett. This includes electricity use for recycling and site-specific data. Table 3 below presents site specific data collected from the recycling plant. Electricity is used in the recycling process. The final product is granulated material which will be used for manufacturing of new PVC flooring. There will still be around 17 percent material which cannot be recycled and will be sent to a waste-to-energy plant.

**Table 3. Recycling process data.**

Category	Unit	Value
<b>Energy input</b>		
Electricity	MJ/ton residue flooring	16.7
<b>Material output</b>		
Recycled product	ton/ ton residue flooring	0.83
Waste to incineration	ton/ ton residue flooring	0.17

### 3.2.2.2 Generic process data

Environmental data regarding upstream ingredients were extracted from GaBi thinkstep LCA database and Ecoinvent 3.5 database. These data represent environmental impacts of materials from cradle to gate boundaries. Data were selected using EU-28 average data and global average data for a generic assessment.

### 3.2.2.3 Transportation data

Residue flooring EOL system involves transportation. The system boundary is set in Sweden and the transportation type is by truck. Three main transportation routes are used in the system:

- From construction/renovation site to recycling plant in Ronneby

Construction/renovation sites are spread around Sweden, but most materials come from Gothenburg, Malmö and Stockholm region. It was estimated around 300 km in average for collection.

- From construction/renovation site to waste-to-energy plant

It was assumed that uncollected residue flooring is sent to waste-to-energy plants. A distance of 100 km in average was assumed in this case.

- Recycling plant to waste-to-energy plant

A part of residue flooring cannot be recycled and is therefore sent to a waste-to-energy plant. The distance between the recycling plant and waste-to-energy site was estimated to 100 km.

### 3.2.3 Modelling in GaBi

The software used for modelling is GaBi ts, program version 8.7.10.18. Each scenario was analysed separately. In the figures below, flow schemes of residue flooring EOL system are presented.

#### 3.2.3.1 Present scenario

“Present scenario” was modelled according to residue flooring collection data for 2018. It is assumed that there are 1800 tons residue flooring generated in total in Sweden while only 334 tonnes have been collected in 2018. Figure 11 presents the residue flooring distribution between recycling and incineration.

##### Scenario 1. Present scenario

Process plan:Reference quantities  
The names of the basic processes are shown.



Figure 11. Present case scenario in GaBi modelling.

#### 3.2.3.2 Future Scenario

“Future scenario” assumes that the residue flooring collection rate can reach 100 percent. The results can be used to show the potential big difference in environmental performance compared to current situation.

##### Scenario 2: Future scenario

Process plan:Reference quantities  
The names of the basic processes are shown.

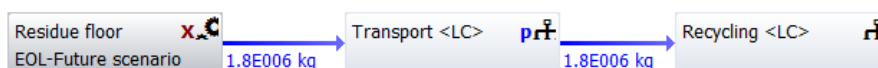


Figure 12. Future case scenario in GaBi modelling

### 3.3 Results from modelling and interpretation

The results of this study are valid for the Swedish system for collection and recycling of residue PVC flooring for the year 2018. The results need to be considered in connection to the geographical boundary, Sweden, especially regarding the energy source. Sweden has low carbon emissions value for energy production compared to the European average value. The energy recovery from flooring incineration was considered as Swedish energy with the respective low carbon emissions values. Transportation distances were assumed on the average domestic distance.

Figure 13 reflects the GWP of the two scenarios expressed in CO<sub>2</sub>-eq. For the present scenario, only around 18 percent of total residue flooring generated in Sweden was collected through the system. The rest of 82 percent were not collected through the system and it is assumed that they were sent to incineration plants for energy recovery. For this reason, the biggest contribution of climate impact comes from the incineration process.

In the present scenario more than 2 000 tons CO<sub>2</sub>-eq emissions are generated. The recycling part in the present scenario gets a small credit in the analysis. In the future scenario emissions from production of virgin PVC material are avoided and this is reflected in a ‘negative impact’ in the figure. This indicates the GWP which can be avoided by using recycled PVC instead of virgin PVC.

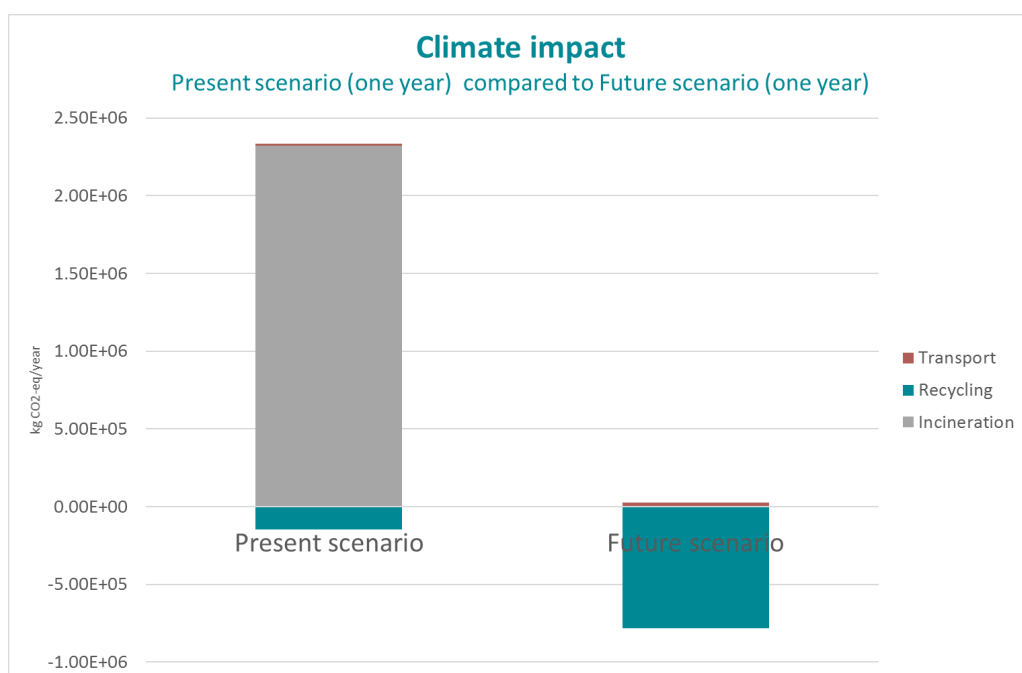


Figure 13. Total climate impacts from residue flooring generated in one year in the two scenarios

A comparison between incineration and recycling of one tonne of residual material is presented in Figure 14. Treatment through incineration with energy recovery includes emissions from incineration of plastic. But because this process also generates heat and electricity, this will help avoid emissions from generating the same energy from other sources and this is reflected in the analysis. In the same way, using recycled PVC in the production of new floorings will avoid emissions from production process of virgin PVC. This is also considered in the analysis.

Figure 14 shows that incineration of one ton of residue flooring causes 1600 kg CO<sub>2</sub>-eq emissions in total. While if this one-ton flooring goes to recycling, the impact is around -400 kg CO<sub>2</sub>-eq. This is mainly because recycling one-ton residue flooring can reduce the virgin material consumption and therefore will avoid the environmental impact coming from that. The avoided emissions from not using virgin PVC are around -900 kg CO<sub>2</sub>-eq (yellow part in the figure 14).

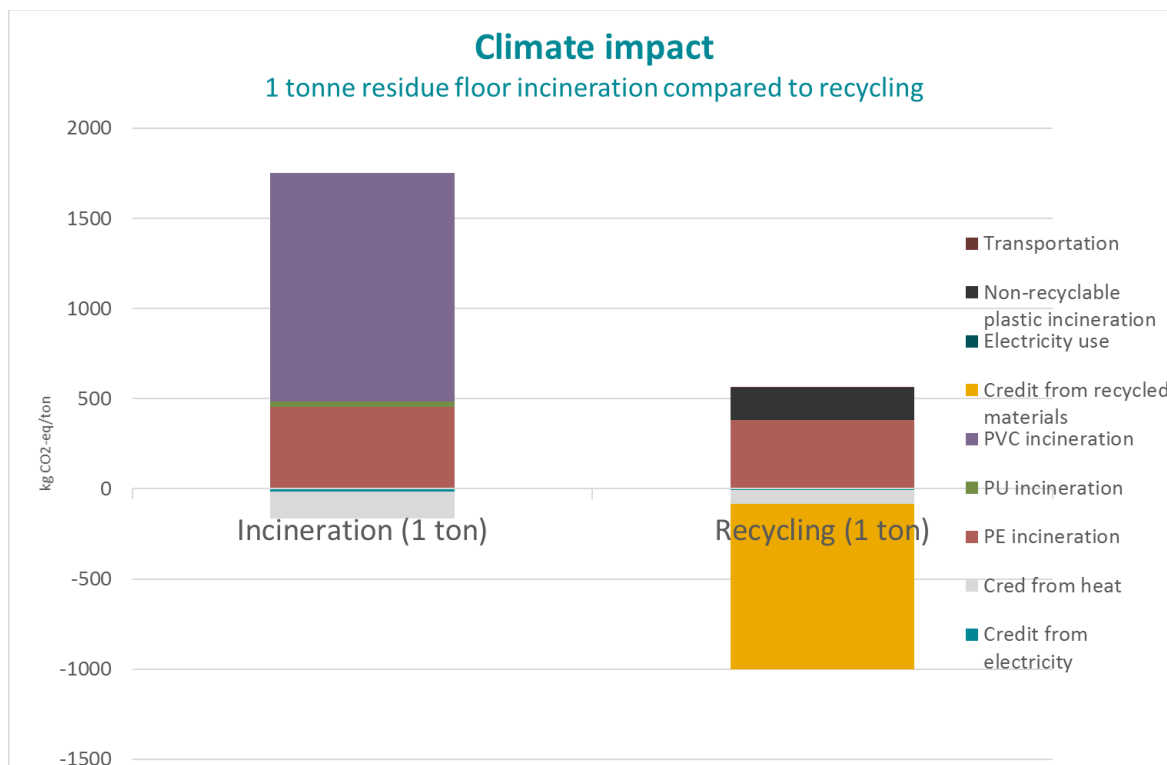


Figure 14. Climate impact from incineration and recycling of one tonne of flooring residue.

Incineration of residue flooring for energy recovery generates a large amount of greenhouse gas (GHG) emissions. Of course, during the incineration process, a certain amount of energy will be converted into electricity and heat. Figure 15 presents the detailed impact distribution of residue flooring incineration. Most of impacts come from PVC and PE incineration which contribute to almost all GWP impacts. The avoided emissions from electricity and heat generated from flooring incineration contribute with quite a small reduction to the whole picture.



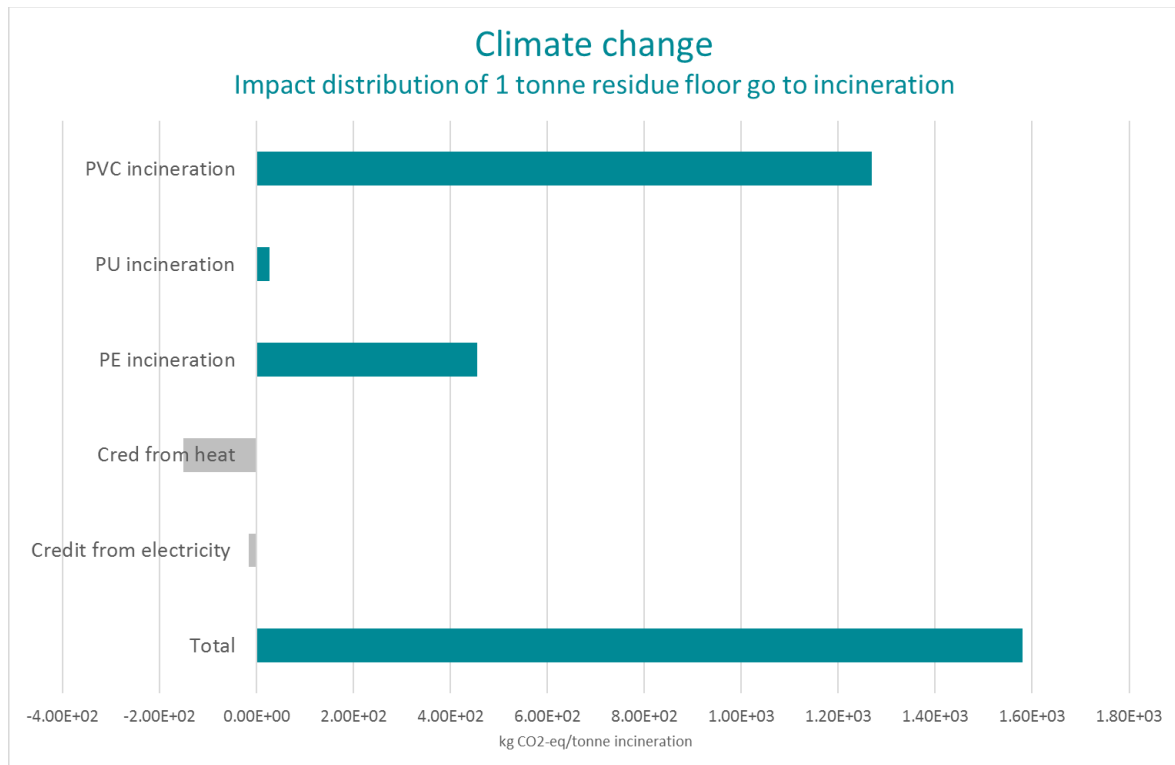


Figure 15. Impact distribution from energy recovery of one tonne of flooring residue.

Granulation of the residue material requires electricity use. The electricity demand for one tonne of residue flooring is only 16.7 MJ which is almost neglectable. The sorting process includes separation of unrecyclable material which is sent to incineration with energy recovery. The rest goes through recycling and then is sent back to the manufacturing step. Incineration generates electricity and heat which are given a credit in the modelling. Recycled materials replace virgin material in the manufacturing phase. As illustrated in figure 16 the major benefit from recycling is the credit from the virgin material replacement. The credit from flooring material saving is -900 kg CO<sub>2</sub>-eq per ton residue flooring recycling.

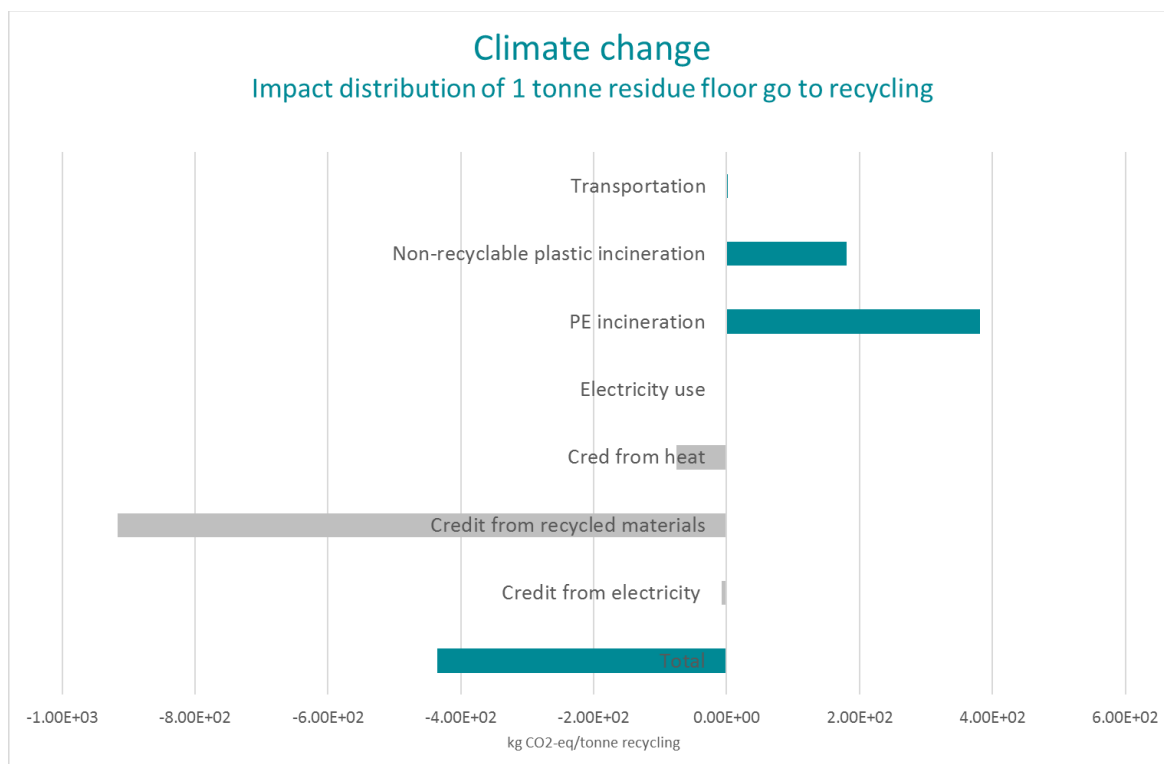


Figure 16. Impact distribution from recycling of one tonne of flooring residue.

One important factor which influences the results of the LCA study is the geographical boundary, which in this case is Sweden. The energy use and energy recovered are all based on the Swedish context. In order to illustrate this, results based on European energy are included in Appendix C.2 for readers to have a better understanding of the values for GWP presented in this report.

## 4 Opportunities and barriers for increased collection and recycling

Companies that install flooring in different parts of Sweden as well as public and private purchasers of such services were interviewed in this study.

The overall conclusion from the interviews is that the system for collection and recycling of plastic flooring installation residue works well for those that use it and the interviewed flooring installation companies are in general satisfied with it. However, a relatively low share of installers uses the system consistently today and many purchasers of flooring installation services do not know about it.

The main reason for using the system which was underlined by the interviewed companies was that this helps them have an environmentally friendly company profile. Some of the companies mentioned they have an environmental performance certification and the fact that they recycle this material helps them to receive the certification or obtain a better assessment. Some also mentioned that they use the system to be able to market themselves as environmentally friendly and therefore achieve competitive advantage.

It was also mentioned that using the system is cost efficient as the companies do not have to pay for waste collection and management services themselves. It is free of charge for the members of the Swedish Flooring Association to use the collection system. This reduces waste management costs for the companies.

Good logistics on the construction/renovation site as well as commitment from the companies installing the flooring were named as important factors to enable the use of the system. At present, most of the flooring residue is either collected in the plastic waste container together with other plastic fractions or collected in the container for combustible waste. Separate collection of the plastic flooring residue requires an extra container, and this can be a challenge as space is limited on these sites. Separate collection of plastic flooring residue must therefore be set as a priority and commitment from the workers is needed to separately collect the material. Training is necessary for the workers that install flooring to understand why separate collection of residue flooring is so important.

The following section presents a discussion on the barriers and opportunities for increasing the quantity of collected material for recycling in Sweden as identified in this study.

### Lack of awareness

The main barrier for using the separate collection system is the lack of awareness of the system's existence and how it works. This is the case for both some of the flooring installing companies and especially for the organisations that purchase the flooring installation services.

Some of the interviewees consider that the Swedish Flooring Association has a very important role to play in this regard. They consider that the association should accelerate the work to increase awareness of the system among actors from the industry, as well as other industries. Examples of activities can be participation in different conferences and events to present the collection system and how it works. More information through different media channels is another example of how information on the system can be spread. This can increase the visibility of the system and the collection rate of flooring residue.

### No requirements from purchasers

Very few purchasers of plastic flooring installation services set requirements in tender documents/agreements for separate collection of the installation residue.

Two of the stakeholders contacted for an interview mentioned that their organisation has set such a requirement in the tender for a framework agreement for flooring installation services or in the purchasing agreement. This is a rather new practice and still very few organisations set such requirements.

The following text was a part of the tender documents of one of the interviewed organisations (translated from Swedish):

*'Requirement for management of flooring residue from installation*

*The selected supplier should manage the residue generated during the installation of plastic flooring and flooring which is PVC-free and should have a system for returning the material to the flooring manufacturers. This in order to enable recycling.'*

Such requirements will create incentives for more companies to use the system and increase the recycling rate of this material. This aspect was identified as important by all the interviewed

companies which install plastic flooring. The argument was that if the client sets such a requirement, they will implement it.

Requirements from clients might also incentivize all plastic flooring manufacturers to develop recycling solutions for the residual material from their products.

### Engagement from all manufacturers and recycling solutions for all the materials

Tarkett only recycles material from its own products today and this might also be a barrier to increase collection rates. The fact that material from six out of nine manufacturers is sent to incineration even though it is collected through the joint collection system might affect the motivation among some actors to use the collection system.

Forbo and Altro took back their material for the first time in 2018 and Forbo confirmed they sent the 40 tons of material for recycling at their manufacturing plant in The Netherlands.

Transparency on how the system is operated is important. It is also important to engagement all the other manufacturers to develop solutions for recycling of the materials from their own products. The Swedish Flooring Association can take a leading role to engage the other manufacturers to 1) develop recycling solutions which could motivate higher collection rates and 2) to increase awareness among their customers about the possibility of separate collection of the material.

### Standard practice within the industry

It was mentioned that separate collection and recycling of installation residue should become a standard practice in the industry, especially since there is already a system in place today. At present only around a fifth of the residual material generated during the installation process is collected through the system, making this practice rather the exception not the rule.

Setting goals to reduce the amount of waste which is sent to energy recovery among different stakeholder in the industry can also contribute to increasing the collection rate through the system. One of the interviewed purchasers mentioned they have set such an objective. Separate collection of flooring residue and management thorough the system helps them reach their objective. Communication throughout the entire company about this goal and continuous monitoring of the implementation though periodic reports have been named as important to achieve such a goal.

### User-friendliness

Even though the installing companies say the collection system works well for them, they still see potential for improving the user-friendliness of how the material is collected by employees during flooring installation. It was mentioned during the interviews that the collection of material residue in the transparent sack during the installation can be difficult for some of the installers. The installers need to carry the sack with material from room to room and from floor to floor. This might slow down the installation process. Improving the method for moving the sack intended for collection could potentially help increase the engagement of the installers.

## 5 Conclusions

Separate collection and recycling of residual material from PVC flooring installation is possible in Sweden since 1998. However, only around a fifth of all the residue material generated per year is collected through the existing national joint system while the rest is collected as combustible waste on construction/renovation sites and is sent to incineration with energy recovery.

The LCA in this study indicates that this current practice has a considerable climate impact. Within the boundaries of this study, each ton of residual PVC flooring which is incinerated for energy recovery in Sweden generates emissions of 1600kg CO<sub>2</sub>-eq. The study also shows that if that one ton of material is instead recycled it contributes to climate savings of -400 kg CO<sub>2</sub>-eq. In other words, recycling one ton of PVC flooring residue in Sweden instead of sending that material to incineration with energy recovery will reduce the climate footprint of a company with 2ton CO<sub>2</sub>-eq/ ton PVC-flooring.

From the total material collected through this joint industry system, Tarkett recycles today material only from its own products in the plant located in Ronneby. Therefore, a major opportunity exists to increase recycling rates of the material coming from products manufactured by the other companies which are members in the joint system as well. From 2018 two of the other eight manufacturers required to receive back their material and one of them confirmed that the material is recycled back into manufacturing in The Netherlands. It is important to strengthen the engagement from all the other manufacturers to develop solutions for recycling of the materials from their own products. The Swedish Flooring Association has initiated dialog with the other manufacturers for them to take back their materials or to find a joint recycling solution in Sweden. However, some of the interviewed actors consider that the association should increase its efforts in this regard.

Lack of awareness that this system exists and information about how to use it is a major barrier today to increase the collection rate, but also the biggest opportunity. Efforts have already been made by the Swedish Flooring Association and Tarkett AB in this regard. However, shifting the focus from the companies installing the flooring to the purchasers of flooring installation services could be a good next step. All the interviewees in this study have indicated that few purchasers set such requirements as many are unaware of the existence of the separate collection system. Information about how to include such requirements in tender documents and framework contracts for flooring installation services has the potential to increase the collection rate through this system.

Even though this collection and recycling system for plastic flooring in Sweden can be further improved, it remains a good example of how the construction industry can strive to develop more closed loops for the materials it uses. Therefore, the system should become a source of inspiration to develop similar systems and increase recycling of other C&D waste fractions as well.

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# Appendix A. List organisations represented in the interviews/data collection

Flooring installing companies:

- BBM Golv och bad
- BL Interior
- Golvet Göteborg
- Sandens Golv

Purchasers of services for installation of flooring:

- Helsingborg Stad
- Göteborg Stad
- Västra Götalandsregionen
- NCC

## Appendix B. Brief introduction to LCA

Environmental life cycle assessment (LCA) is the calculation and evaluation of the environmentally relevant inputs and outputs and the potential environmental impacts of the life cycle of a product, material or service (ISO 14040:2006 and 14044:2006).

Environmental inputs and outputs refer to demand for natural resources and to emissions and solid waste. The life cycle consists of the technical system of processes and transports used at/needed for raw material extraction, production, use and after use (waste management or recycling). LCA is sometimes called a "cradle-to-grave" assessment (figure 1).

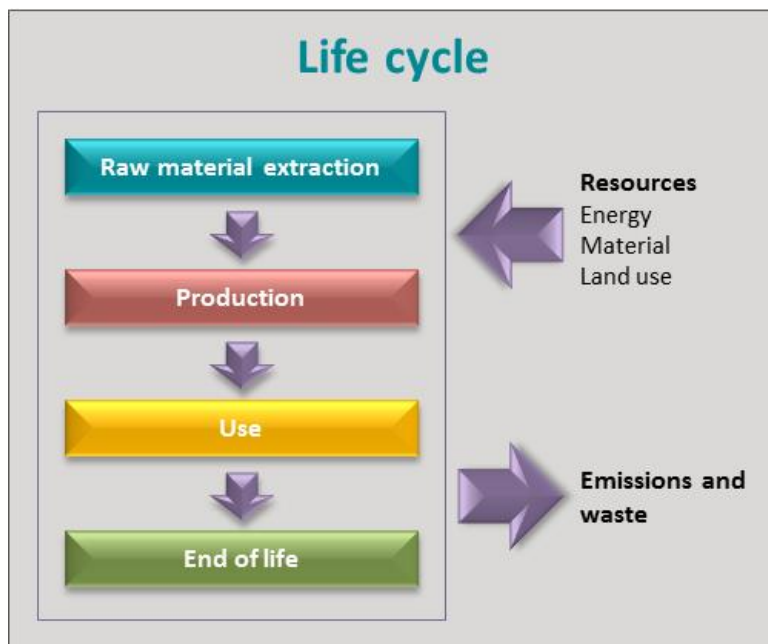


Figure 1: Illustration of the LCA system.

An LCA is divided into four phases. In accordance with the current terminology of the International Organization for Standardization (ISO), the phases are called goal and scope definition, inventory analysis, impact assessment, and interpretation (figure 2).

An LCA can be used in many different ways, depending on how the goal and scope are defined. Product development, decision making, indicator identification and marketing are examples of areas where the information retrieved from an LCA may be valuable.



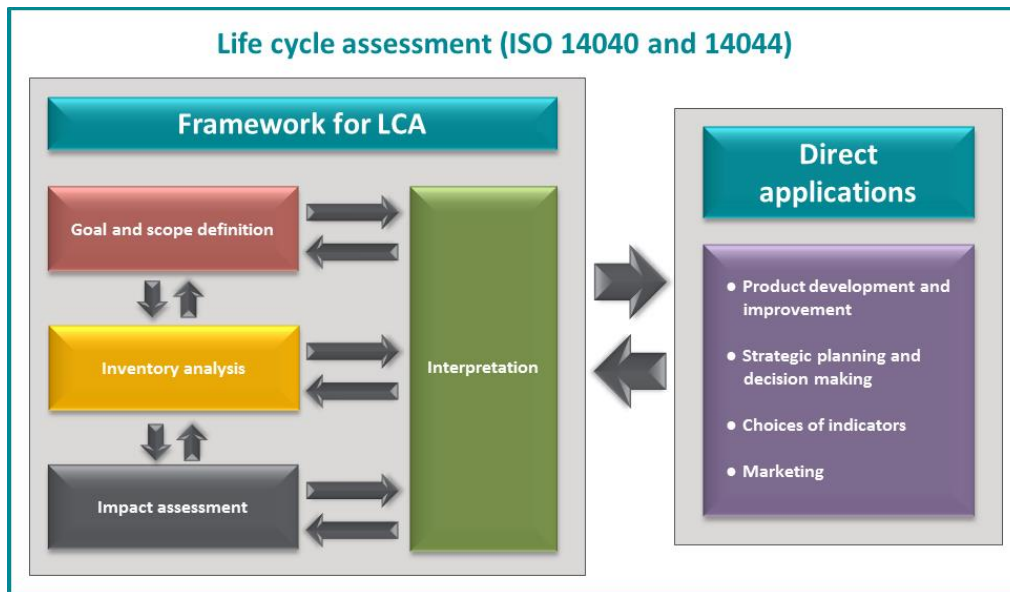


Figure 2: Illustration of the phases of an LCA.

### **Goal and Scope**

In the first phase the purpose of the study is described. This description includes the intended application and audience, and the reasons for carrying out the study. Furthermore, the scope of the study is described. This includes a description of the limitations of the study, the functions of the systems investigated, the functional unit, the systems investigated, the system boundaries, the allocation approaches, the data requirements and data quality requirements, the key assumptions, the impact assessment method, the interpretation method, and the type of reporting.

### **Inventory analysis**

In the inventory analysis, data are collected and interpreted, calculations are made, and the inventory results are calculated and presented. Mass flows and environmental inputs and outputs are calculated and presented.

### **Impact assessment**

In the life cycle impact assessment (LCIA), the production system is examined from an environmental perspective using category indicators. The LCIA also provides information for the interpretation phase.

For comparative assertions, there are four mandatory elements of LCIA:

Selection of impact categories, category indicators and models,

Assignment of the LCIA results (classification),

Calculation of category indicator results (characterization) and

Data quality analysis.

The following elements are optional:

Calculating the magnitude of category indicator results relative to a reference value (normalization),

Grouping and

Weighting.

### **Interpretation**

The interpretation is the phase where the results are analysed in relation to the goal and scope definition, where conclusions are reached, the limitations of the results are presented and where recommendations are provided based on the findings of the preceding phases of the LCA.

An LCA is generally an iterative process. The impact assessment helps increasing the knowledge about what environmental inputs and outputs are important. This knowledge can be used in the collection of better data for those inputs and outputs in order to improve the inventory analysis.

The conclusions of the LCA should be compatible to the goals and quality of the study.

## **B.1 Category definition, classification and characterisation**

For each impact category  $i$ , the reasons why the environmental impact is considered to be an environmental problem are described. The category indicator – the quantified representation of the environmental impact – is defined, and the mechanisms that are modelled in the characterisation are described in brief. The characterisation factor describes the potential contribution to the impact category  $i$  from the input or output of substance  $j$  per unit mass of  $j$ . The total contribution to the impact category from the life cycle,  $C_i$ , is calculated as:

$$C_i = \sum E_j \cdot W_{ij}$$

where  $E_j$  is the amount of the input or output of substance  $j$ .

### **Global warming**

A global climate change is a problem for many reasons. One is that a higher average temperature in the seawater results in flooding of low-lying, often densely populated coastal areas. This effect is aggravated if part of the glacial ice cap in the Antarctic melts. Global warming is likely to result in changes in the weather pattern on a regional scale. These can include increased or reduced precipitation and/or increased frequency of storms. Such changes can have severe effects on natural ecosystems as well as for the food production.

Global warming is caused by increases in the atmospheric concentration of chemical substances that absorb infrared radiation. These substances reduce the energy flow from Earth in a way that is similar to the radiative functions of a glass greenhouse. The category indicator is the degree to which the substances emitted from the system investigated contribute to the increased radiative

forcing. The characterisation factor stands for the extent to which an emitted mass unit of a given substance can absorb infrared radiation compared to a mass unit of CO<sub>2</sub>. As the degree of persistence of these substances is different, their global warming potential (GWP) will depend on the time horizon considered, such as 20, 100 and 500 years. In this study, a time horizon of 100 years has been applied. The time scale 100 years is often chosen as a “surveyable” period in LCAs and discussions regarding global warming.

The characterisation of this environmental impact takes into account the substances that contribute directly to the greenhouse effect. The total contribution to the global warming potential from the life cycle is calculated as:

$$\text{GWP} = \sum \text{GWP}_j \cdot E_j$$

where  $E_j$  is the amount of the output  $j$  and  $\text{GWP}_j$  the characterisation factor for this output. The characterisation factor is measured *in g CO<sub>2</sub> equivalents per g of the emitted substance*, and thus, the unit of the category indicator is *g CO<sub>2</sub> equivalents (g CO<sub>2</sub> eq.)*.

# Appendix C. GaBi datasets selection in models

## C.1 GaBi datasets selection in models

Table 4. Datasets selected for residue flooring materials and energy used in Gabi models

Upstream data	Short name	Data set	System boundary	Data source	Year
Polyvinyl chloride	PVC	Polyvinyl chloride granulate (PVC) (DE) thinkstep <LC>	Cradle to gate	thinkstep	2017
Mineral fillers	Filler	EU-28: Talcum powder (filler) ts	Cradle to gate	thinkstep	2017
1,2 Cyclohexanedicarboxylic acid, diisononylester	DINCH	DE: Polyester Resin unsaturated (UP)	Cradle to gate	thinkstep	2017
Epoxidised soya bean oil	Epoxidised soya bean oil	RoW: esterification of soybean oil ecoinvent 3.5	Cradle to gate	ecoinvent 3.5	2018
Stabilizer CaZn	Stabilizer	GLO: Soaping agent (phosphonic acid and foam stabilizers) ts	Cradle to gate	thinkstep	2017
Titanium dioxide and other pigments	TiO2	RER: titanium dioxide production, sulfate process ecoinvent 3.5	Cradle to gate	ecoinvent 3.5	2018
PUR surface treatment	PUR	EU-28: 2-component PUR adhesive based on polyether and castor oil (estimation) ts	Cradle to gate	thinkstep	2017
Electricity	Electricity	SE: Electricity grid mix 1kV-60kV ts	/	thinkstep	2 014

## C.2 Results based on European average situation

Figures listed in this section present results based on the assessment with European average electricity and heat. The European average electricity and heat have higher carbon footprint than Swedish one. For this reason, results are quite different from the Swedish one. The avoided emissions from generated energy are also much higher than the Swedish one.

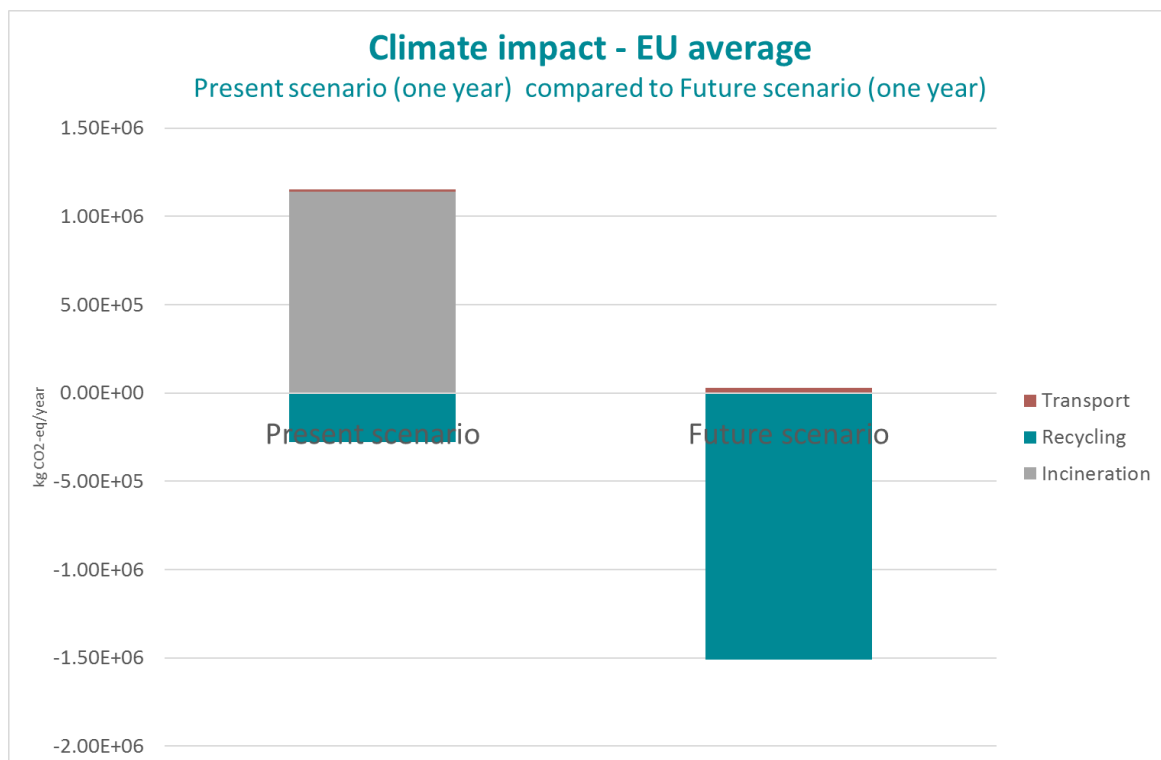


Figure 17 Total climate impact based on European average energy situation. Impacts from residue flooring generated in one year regarding the present scenario and future scenario. The results are presented in three parts, incineration, recycling and transportation which contribute separately.

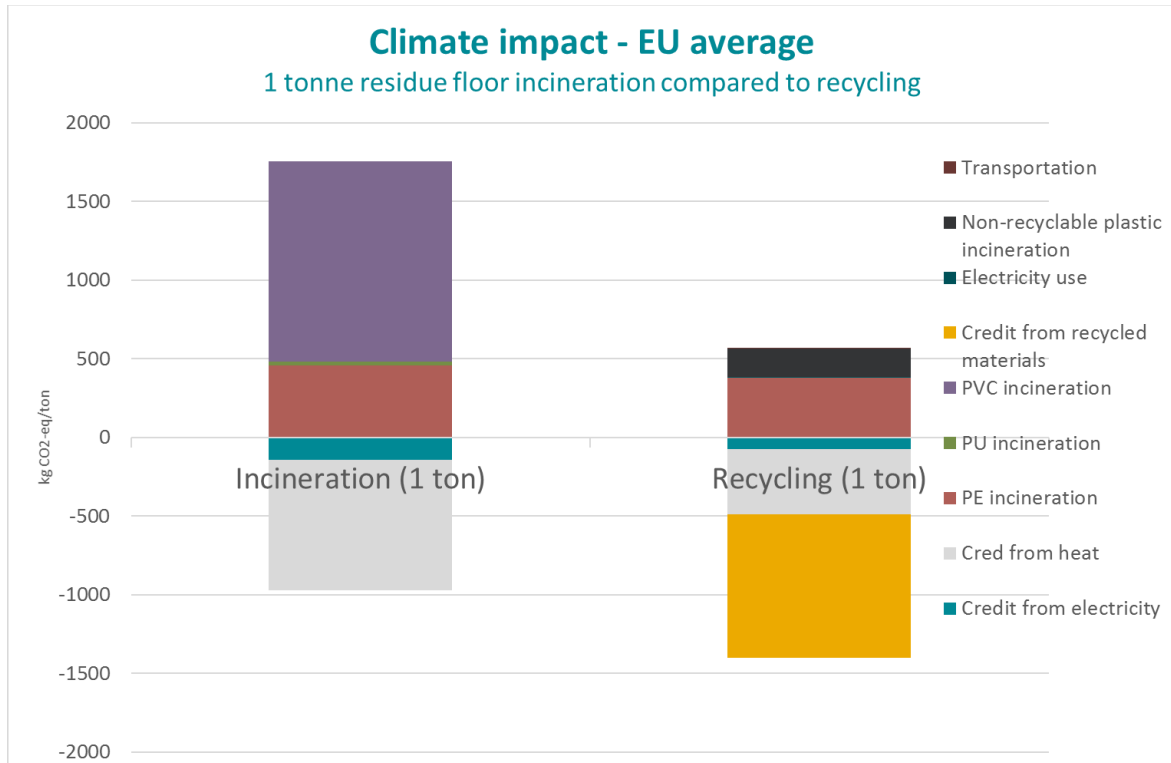


Figure 18 Climate impact comparison between incineration process and recycling process for one tonne residue flooring based on European average energy situation.

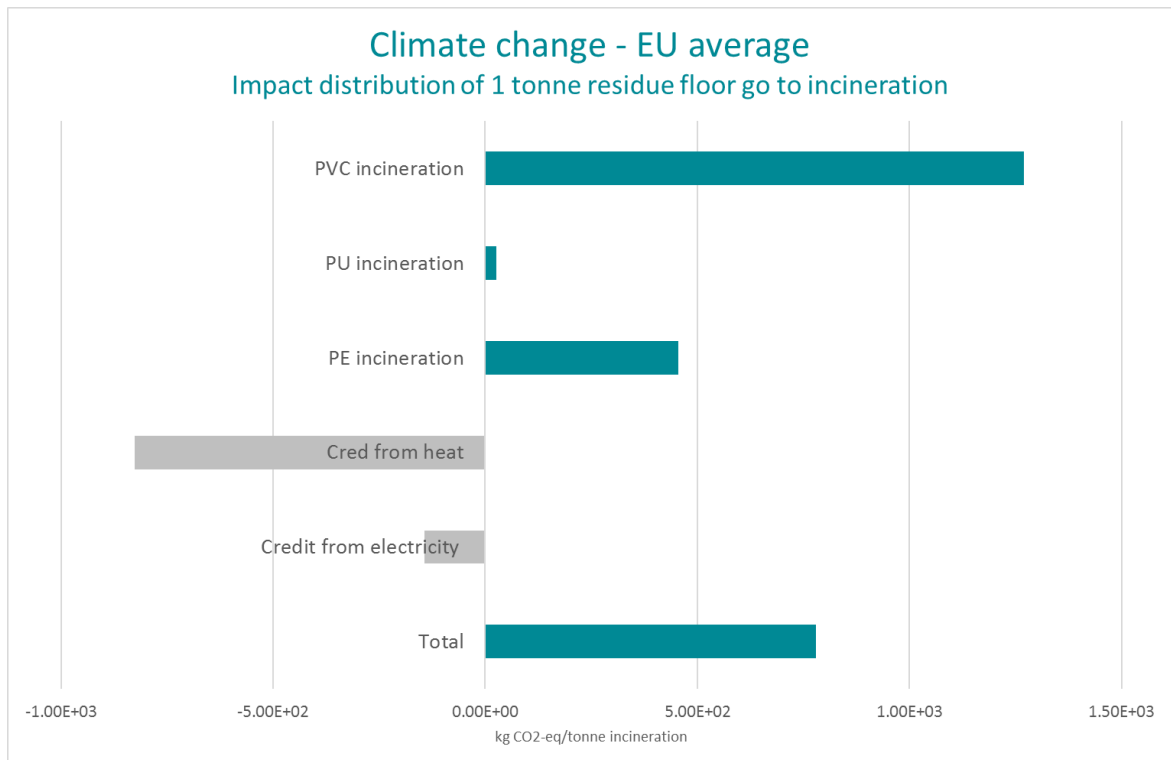


Figure 19 Impact distribution from incineration of one tonne residue flooring based on European average energy situation.

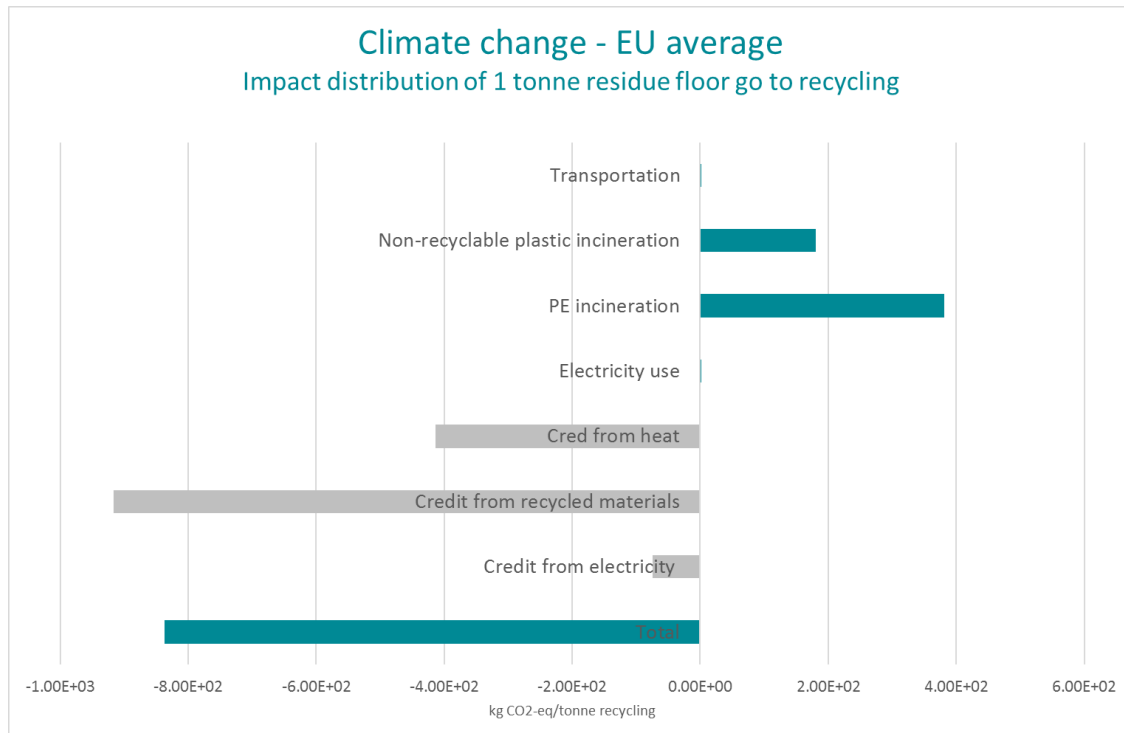


Figure 20 Impact distribution from recycling of one tonne residue flooring based on European average energy situation.



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