Research into the Sustainable Potential of Circular Furniture Materials and Production based on the Circular Economy

A CooLoo case study

MAR710

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Cover page

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I confirm that I give permission for my dissertation project to be made available for further academic purpose. (For further research, questions or publications, the University needs to contact CooLoo or the author.)

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5. Findings

This present chapter presents the findings of the primary research collection regarding the research questions and the overall research aim. Therefore, the author analysed individual codes to identify all relevant findings and present them in a structured and easily understandable manner.

Codes
1) CooLoo Experts
2) Suppliers
3) Transportation
4) Circular Economy
5) Environmental Product Declaration
6) Material Circularity Indicator
7) Environmental Footprint

Table 7: Codes (Author, 2021)

The table above presents the previously mentioned codes, which were analysed to present the findings structured. As it can be seen, seven codes are presented. The first code is called “CooLoo Experts”, and it summarizes the findings of the interviews conducted with the experts of CooLoo. The second code is called “Suppliers”, and it presents the findings of the interviews conducted with suppliers of CooLoo. The following code, “Transportation,” summarizes the findings of all interviews regarding the means of transportation of either the suppliers as well as CooLoo itself. The code “Circular Economy” presents all findings of all interviews interview questions regarding the circular economy. The following code, “Environmental Product Declaration”, presents all findings of all interview questions regarding the Environmental Product Declaration. The code “Material Circularity Indicator” displays the findings of all interview questions regarding this topic and all relevant data and numbers. Finally, the last code, “Environmental Footprint”, presents the findings of all interview questions regarding this topic and all relevant data and numbers.

5.1 CooLoo Experts

Based on the expert interviews with the experts of the company CooLoo, several findings can be drawn. CooLoo´s experts state that when producing the products, they use four different main raw materials, which are composed together in the form of layers that generate the desired product. The first layer is made of the raw material polyether foam. Approximately 40 kg per m³ of this raw material are required. The second layer is made of webbing. Approximately 400 grams per m² of this raw material are required. The third layer is made of polyurea, from which approximately 2 kg per m² are needed. The last layer is made of the finishing, which is made out of water-based glue and recycled materials. For the water-based glue, approximately 150 grams per m², and for the recycled material, approximately 500 grams per m². (Interview 1, 2021) The CooLoo experts state that the overall aim is to aspire endless life products, which can be refurbished over and over again. At the moment it is assumed that the products have a life span of at least 70 years when used properly. Nevertheless, it is difficult to estimate the actual lifespan, as the company and the techniques were invented in 2013 and therefore, the actual lifespan couldn´t be tested. (Interview 1, (2021) Furthermore, the findings of the interviews with the CooLoo experts present where the customers are located. The majority of the customers are located in the Netherlands, Belgium, and Germany, mainly the Ruhrgebiet. The main regions in the Netherlands are Utrecht, Amsterdam, Den Haag and Rotterdam, and in Belgium, the main regions are Antwerp and Brussel. These are the significant regions because there are big office markets with large densities of people and offices. Furthermore, the CooLoo experts state that they prefer to work with customers located within a 300 km radius around CooLoo´s location. That makes transportation and refurbishment more efficient. (Interview 2, 2021)

5.2 Suppliers

Based on the conducted interviews with the CooLoo experts, findings regarding the relevant suppliers of CooLoo can be drawn. As information about CooLoo´s suppliers are required for further research, diving further into this topic is essential. The experts state that CooLoo cooperates with four main suppliers. All these suppliers are located in Europe, as CooLoo doesn´t see the benefit in collaborating with suppliers located on other continents as it restricts the means of transportation and communication. The first supplier of CooLoo supplies the finishing and the glue and is located in the Netherlands, 11,4 km away from CooLoo´s location. The second supplier of CooLoo supplies polyurea and is based in Italy, 1032 km away from CooLoo´s location. The third supplier of CooLoo supplies the webbing and is based in Germany, 447 km away from CooLoo´s location. The last supplier of CooLoo supplies the polyether foam and is located in Belgium, 150 km away from CooLoo´s location. Moreover, the experts state that when selecting the most suitable suppliers, they not only concentrating on the location of the suppliers but also on the fact if they believe in the concept of the circular economy and if they are willing to develop new materials and techniques which could benefit the circular economy. (Interview 2, 2021)

5.3 Transportation

Based on the conducted interviews, findings regarding the transportation of the company CooLoo and the suppliers can be drawn. The interviews put there that CooLoo uses company own trucks as a means of transportation to transport the products to the customers. Therefore, they try to combine as many routes as possible and deliver as many customers as possible in the most efficient procedure. After the end of the product of life, the product needs to be refurbished, wish takes place at CooLoo´s manufacturing site. Therefore, CooLoo again uses trucks to collect the used products at the customer's locations and transport them back to the manufacturing site. Another possible scenario is that CooLoo´s employees can conduct the refurbishment of the used products at the customer's location, minimising the use of transportation for CooLoo. Again, CooLoo tries to combine the routes to deliver the products and the routes to collect the used products to maximize the number of served customers most efficiently. Finally, it needs to be mentioned that the scenario can occur, in wish the customers take care of the transportation by themselves, which minimizes the use of transportation for CooLoo. (Interview 2, 2021) When looking at the suppliers of CooLoo, and how the raw materials are transported to the manufacturing site, it needs to be stated that all the suppliers are located in Europe and are, therefore, relatively close located to CooLoo´s manufacturing site. The reason for that is that CooLoo doesn´t see the benefit of supplying raw materials from other continents just because the materials could be cheaper. CooLoo is more aware of the fact that it would make transportation as well as communication more difficult. Furthermore, the raw materials could be of poorer quality. As CooLoo doesn´t import anything via cargo ships or planes and instead uses local suppliers, all the transportation can be done by road transportation in the form of trucks. (Interview 2, 2021) When looking at the interviews conducted with CooLoo´s suppliers, it can be said that all the suppliers of CooLoo´s suppliers are located in Europe as well. Therefore, the raw materials are all transported by truck from the suppliers to CooLoo´s suppliers. CooLoo´s suppliers make use of the service of a transport company, which transports the raw materials to the customers with the use of trucks. Only a few customers are located on other continents, which requires plane and cargo ship transportation, which the transport company also conducts. CooLoo´s suppliers state that they do not have a limit on the distance when suppling customers. (Interview 3, 2021)

5.4 Circular Economy

Based on the conducted interviews, findings regarding the circular economy of the Company CooLoo and their suppliers can be drawn. First of all, it needs to be stated that the circular economy was not the company's core value when it was founded in 2013. Nevertheless, they wanted to change the present industry by making it more sustainable and more efficient using new technologies. That led to less waste being produced, which is also part of the circular economy. Then over the years, CooLoo developed more sustainable technologies and materials, and they noticed that the circular economy concept worked very well. When CooLoo recognized the concept, they noticed that they already adopted some parts. Thereupon, CooLoo specialised in the concept and began to adopt it into the company structures fully. Nowadays, CooLoo shows the market how they can produce more sustainable and circular waste materials from the Netherlands, the Netherlands' materials, and the Dutch producers and suppliers of materials. CooLoo believes in the circular economy concept because they can not see a future for the linear economy. CooLoo states that products in the linear economy are produced unsustainable, inefficiently, with many extended supply chains, a lot of production steps, which generates a lot of waste, and requires a lot of production steps that require a lot of skilled workforces. Furthermore, CooLoo states that the linear economy drastically increases the number of products thrown away after a few years, which restricts the limited resources. Finally, CooLoo states that their main goal is to generate products with an endless life so that when the customers use the products, they are not thrown away but refurbished and then used again. Furthermore, CooLoo states that their materials contribute to a more sustainable and circular economy because they demonstrate the concept of refurbishment, which is more efficient than recycling products. Therefore, CooLoo refers to the “Value Hill”, which is a figure that demonstrates the differences and benefits of the different concepts. When looking for new suppliers, CooLoo tries to generate partners that believe in the circular economy concept and share their perspectives on the market. (Interview 2, 2021) When looking at CooLoo´s suppliers, it can be said that their customers and suppliers partly follow the concept of the circular economy. They state that not all suppliers and customers have the ability to fully follow the concept, as it depends on the materials they produce and supply. For example, for a company that produces furniture, it could be easier than for a company that produces paint. The same applies to CooLoo´s suppliers. (Interview 3, 2021)

5.5 Environmental Product Declaration

Based on the conducted interviews with CooLoo´s suppliers, the tool Environmental Product Declaration findings can be drawn. One of CooLoo´s supplier state that they use the Environmental Product Declaration to present the environmental performance of the products to their customers. The suppliers state that the main benefit of providing the Environmental Product Declaration to the customers is marketing for their products. Furthermore, it supports the suppliers in presenting their products, life cycles, and the involved stages to the customers. Finally, the suppliers state that as long there is no government obligation to provide an Environmental Product Declaration or another tool, they only concentrate on the marketing benefits. (Interview 4, 2021)

5.6 Material Circularity Indicator

When analysing the material circularity indicator of CooLoo´s products, it is essential to analyse all relevant factors. Therefore, interviews with the experts of CooLoo were conducted. The findings of the interviews show that CooLoo´s experts state that it is difficult to analyse all factors as many techniques and procedures of CooLoo´s processes are still in constant revision and improvement. Moreover, the factors differ when considering that the products need to be entirely produced first and then can be used repeatedly due to the refurbishment. Nevertheless, the experts state that the result of the material circularity index presents a more circular result when the product is refurbished than when it will be produced in the first place. (Interview 1, 2021)

5.7 Environmental Footprint

When analysing the environmental footprint of CooLoo´s products, all four main suppliers of CooLoo need to be taken into account. Therefore, the suppliers of CooLoo were interviewed. Nevertheless, the findings show that not all suppliers can calculate the required data, which is necessary to analyse the environmental footprint. CooLoo´s supplier of the finishing and glue present all required data and which impact these raw materials have on the environmental footprint. All presented data shows the equivalent to a coating surface covering of 8 m^2. They state that they require 15,1393 mg antimony, 56,42765 megajoules of energy, 13,47792 grams of sulphur dioxide, 271,8288 micrograms of Trichlorofluoromethane, 2638,328 grams of CO2, 3250,612 mg of phosphate and 205,0749 mg of ethylene. (Interview 4, 2021) Furthermore, one of CooLoo´s experts states, that it would be very interesting to compare the environmental Footprint of CooLoo´s products with the environmental footprint of similar products in the market, as there are some companies that already calculated the environmental footprint of the products. (Interview 2, 2021).

6. Discussion

This chapter aims to discuss the findings gathered in the previous chapters with the support of the secondary data collection in form of the literature review and the primary data collection, conducted as mono method qualitative study in the form of interviews.

6.1 Transportation

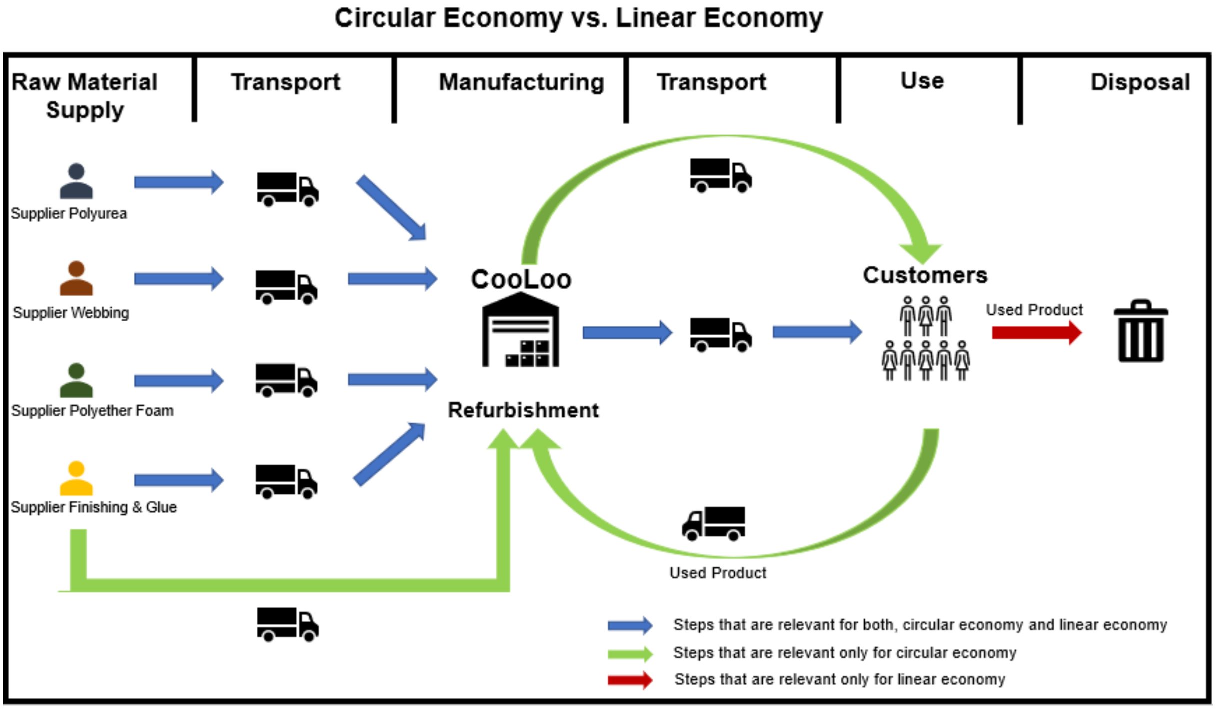

Figure 10: Circular Economy vs. Linear Economy (Author, 2021)

Based on the literature review findings and the primary research in the form of expert interviews, many statements can be drawn. First of all, it can be said that CooLoo follows the concept of the circular economy instead of the linear economy, with the aim to provide the customers with products that aspire to an endless life. Therefore, CooLoo applies steps within the life cycle of its products that differ from steps that would be used within the life cycle of a linear consumed product. The figure above, "Circular Economy vs Linear Economy", shows the main differences CooLoo applies to practice a circular instead of a linear economy. One can say that some steps within an economy are relevant for both the circular and the linear economy, as displayed with the blue arrows. The green arrows display the steps that are only relevant for the circular economy, and the red arrows the steps that are only relevant for the linear economy. The first step is the raw material supply, which is performed by the individual suppliers of CooLoo. The next step is the transportation from the suppliers to CooLoo´s manufacturing site. After that, the manufacturing takes place at CooLoo. After that, the manufactured products are transported to the customers of CooLoo. The previous steps are all displayed as blue arrows and relevant for the circular and the linear economy. After that, the two economies start to strongly opposed each other. After the product is used by the customers and the end of the product´s life is reached, the last stage, the disposal, takes place. This stage is only relevant for the linear economy. Therefore, the product is disposed of and not used any further. As soon as a new product is required, all previous steps must be repeated. When looking at the circular economy, on the other hand, different steps are required. After the end of the products, life is reached, the product is transported back to the manufacturing site of CooLoo. Thereafter, the used product gets refurbished. Therefore, the raw material of one individual supplier instead of all four suppliers is required. After this raw material is transported to the manufacturing site, the refurbishment can be carried out. Finally, the refurbished product can be transported back to the previous customer. These steps can be repeated at any time. In contrast to the linear economy, not all steps need to be repeated, and not all resources are required after the product´s end of life is reached.

Figure 11: Customers, own illustration (Google Maps, 2021)

The figure above shows the region in which most of CooLoo´s customers reside. CooLoo is located in the southeastern part of the Netherlands, close to the German border. Therefore, most of the customers reside in the Netherlands, in the regions around Amsterdam, Rotterdam and Den Haag, and around the regions of the German cities Köln, Düsseldorf and Dortmund. The largest distance between the main regions is between Köln and Amsterdam, which is approximately 214 km. Therefore, the blue circle in the figure shows the circle in which the majority of CooLoo´s customers reside. The red circle in the figure illustrates the average road distance from CooLoo´s location to the customers, which is approximately 120 km. This distance results by taking the two regions into account, with the highest density of customers, Düsseldorf in Germany and Amsterdam in the Netherlands. The road distance from CooLoo to Düsseldorf totals approximately 72 km, while the road distance from CooLoo to Amsterdam totals approximately 167 km. By adding these two numbers and dividing the result by 2, the average distance of approximately 120 km results.

After the average distance to the customers is analysed, the distance to CooLoo´s suppliers must be considered. CooLoo has four main suppliers, which all reside in Europe. The first supplier is Drost Coating. It is the closest supplier and only is approximately 12 km distant from CooLoo. They supply CooLoo with the finishing and glue. The second supplier is Recticel, located in the Netherlands, approximately 150 km away from CooLoo. They supply CooLoo with Polyether Foam. The third supplier is called Zelu. They are located in Germany, approximately 447 km away from CooLoo. They supply CooLoo with webbing. The fourth and last supplier is called Elastopol S.R.L, which is the most distant supplier of CooLoo. They are located in Italy and are approximately 1032 km away from CooLoo. They supply CooLoo with Polyurea. All four suppliers together travel approximately 1640 km to deliver their products to Cooloo.

The analysed distances are required to calculate the total distance covered for CooLoo´s product and the rising CO2 emissions and the resulting extents on the environmental footprint of the products. A standardised road truck produces 0.9 kg of CO2 emissions per travelled km. (Transport & Environment, 2019) The global warming potential shows that climate change occurs due to greenhouse gas emissions and adversely affects humans, ecosystems, and materials. For a period of 500 years, GWP can be expressed with kg CO2 (Carbon dioxide) equivalents. One kg of CO2 emissions that is produced has an impact of 0.05 € on the environmental footprint of a product. (Ozturk and Dincer, 2019) (Ros-Dosdá et al., 2019) The total distance covered for one of CooLoo´s products arises out of the distances from each supplier to CooLoo´s location and the average distance from CooLoo´s location to the customers. By adding all five distances, the total distance of approximately 1760 km results. By multiplying the 1760 km with the 0.9 kg of CO2 emissions per travelled km, the amount of 1583.91 kg of CO2 emissions results, which covers all required distances for one of CooLoo´s products. This result needs to be multiplied with the costs of 0.05 € per kg of CO2 emissions to generate the global warming potential and the transport's impact on the environmental footprint on one product. It shows that the transport has an impact of approximately 79,2 € on the environmental footprint. These numbers are equivalent to one of CooLoo´s products. One product has a life span of approximately seven years. CooLoo practices the circular economy instead of a linear economy, which means that instead of a linear consumption, a closed loop is used in which the generated waste becomes a new resource. Therefore, CooLoo uses refurbishment, which allows to prepare the product after the seven-year lifespan. The product can be used again for another life span of approximately seven years. This process can be repeated several times, yet it is impossible to say exactly how often it can be repeated, as it is a very long process. Therefore, it has not yet been possible to check its full capacity. However, it is assumed that this process can be repeated at least ten times, which would mean that a product has a lifespan of at least 70 years. The purpose of the refurbishment is to generate an endless life product, which means that the product can be reused an endless number of times. (Interview 1, 2021) By practising the circular economy instead of the linear economy, the total amount of km covered by transportation and the resulting CO2 emissions and the impact on the environmental footprint can be reduced by refurbishing the used products instead of producing completely new products each time the life span of a product expired. The following three figures show the circular economy's impact on the total amount of km covered by transportation and the resulting CO2 emissions, and the impact on the environmental footprint, compared to the linear economy.

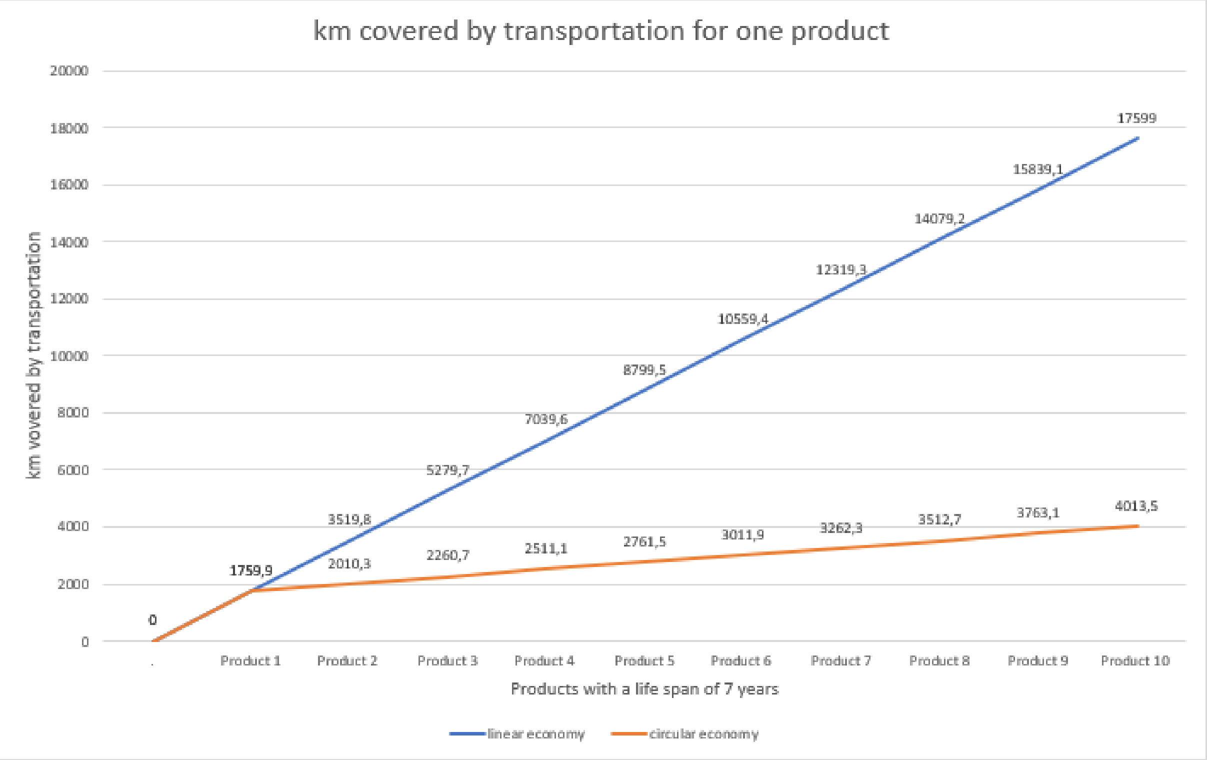

Figure 12: Km covered by transportation for one product (Author, 2021)

The figure above shows the km covered by transportation for one product, for both, if the product is produced in a linear economy, displayed with the blue line and if the product is produced in a circular economy, displayed with the orange line. The vertical axis displays the km covered by transportation, whilst the horizontal axis displays the numbers of products with a life span of approximately seven years. A new product is produced or an already used product refurbished whenever the life span of one product is expired. The figure displays the km coverage of 70 years. As it can be seen, both lines start at zero km and have a total of 1759.9 km covered by transportation after one product is produced, which arises out of the distances from each supplier to CooLoo´s location and the average distance from CooLoo´s location to the customers. After the first product is produced, the two lines start to diverge from each other. The more products are produced, the more significant the difference between the two lines becomes. The blue line rises steadily in a linear fashion. The reason for that is the concept of the linear economy, as after the life span of a product is expired, the same procedure for the new product as well as the km to be transported is required, so each time a new product is produced, another total of 1759.9 km covered by transportation needs to be added. On the other hand, the orange line rises after the production of the first product significantly slower than the blue line. Nevertheless, with the start of the production of the first product, the orange line rises steadily in a linear fashion. The reason for that is the refurbishment of the products used by the second to the last product. By refurbishing the product, only the finishing and the glue and not the other products; therefore, only one of the four suppliers is required. Therefore, only the finishing and glue of the supplier Drost Coating needs to be transported, which covers

11.4 km. Moreover, needs the used product to be transported from the customer back to CooLoo´s location. After the refurbishment is done, the refurbished product needs to be transported back to the customer. That totals 250.4 km which needs to be covered by transportation. That is more than seven times less km that need to be covered by transportation than when reproducing a product and not refurbishing it. Based on this, one can say that each time a product gets refurbished, only 250.4 km instead of 1759.9 km of transportation are required, which explains the strong diverge of the blue and the orange line after the first product is produced.

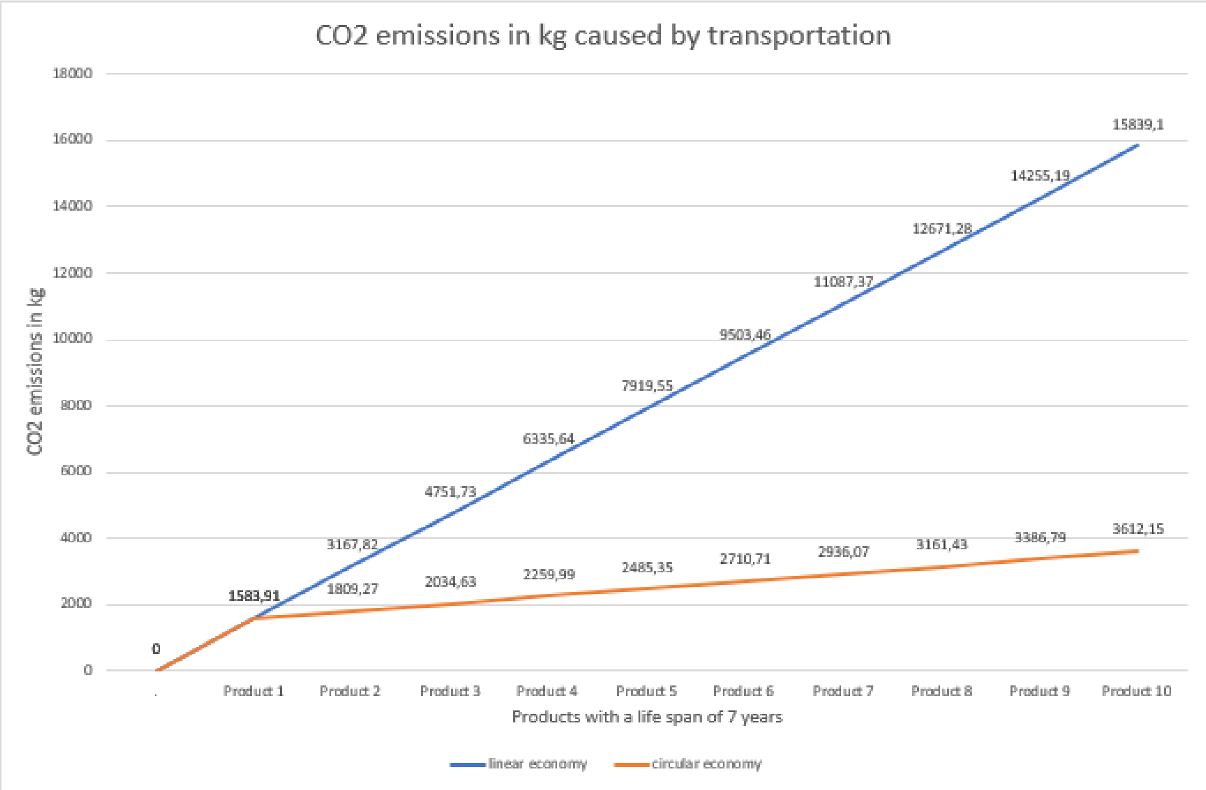

Figure 13: CO2 emissions in kg caused by transportation (Author, 2021)

The figure above displays the CO2 emissions in kg caused by the transportation for one product. For both, if the product is produced in a linear economy, displayed with the blue line and if the product is produced in a circular economy, displayed with the orange line. The vertical axis shows the caused CO2 emissions in kg, whilst the horizontal axis displays, as well as in the previous figure, the numbers of products with a life span of approximately seven years. One can say that the blue and the orange line exhibit an identical behaviour to the two lines in the previous figure. After the first product is produced, both lines exhibit an amount of 1583.91 kg of caused CO2 emissions. After that, the linear economy continues to cause 1583.91 kg of CO2 emissions, whilst the circular economy causes an amount of 225.36 kg of CO2 emissions for any further product that is refurbished. Both lines move precisely as in the previous figure because the CO2 emissions are based on the results of the covered km. The covered km are multiplied by 0.9, which are the CO2 emissions of a truck per km in kg.

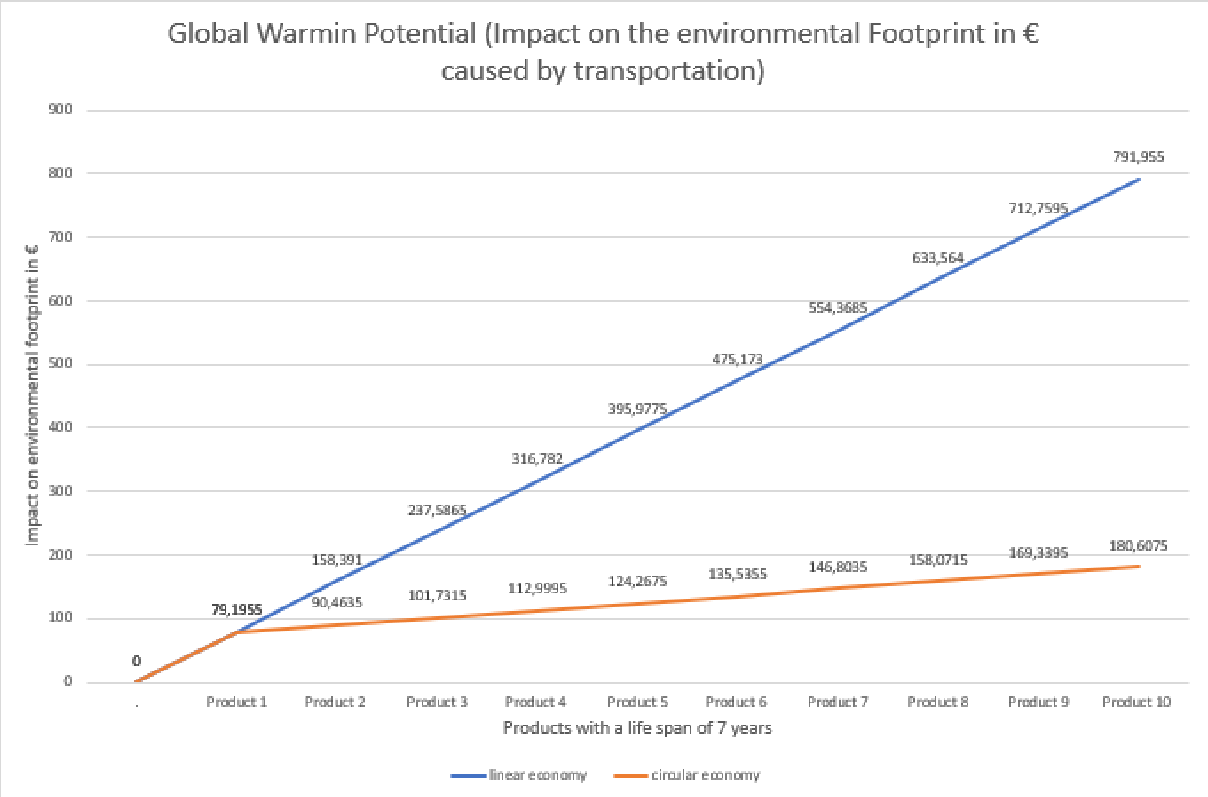

Figure 14: Global Warming Potential (Author, 2021)

The figure above displays the global warming potential, which is the impact of one product on the environmental footprint in € caused by transportation, for both, if the product is produced in a linear economy, displayed with the blue line and if the product is produced in a circular economy, displayed with the orange line. The vertical axis shows the impact on the environmental footprint on the product in €, whilst the horizontal axis displays, as well as in the previous two figures, the numbers of products with a life span of approximately seven years. One can say that the blue and the orange line exhibit an identical behaviour as the two lines in the previous two figures, as they are based on these findings. After the first product is produced, both lines exhibit an impact of 79.1955 € on the environmental footprint of a product. After that, the linear economy continues to have an impact of 79.1955 €, whilst the circular economy causes an impact of 11.268 € on the environmental footprint for any further refurbished product. These numbers are generated by multiplying the analysed CO_2 emissions per kg with the global warming potential of 0.05 € per kg of CO_2 emissions.

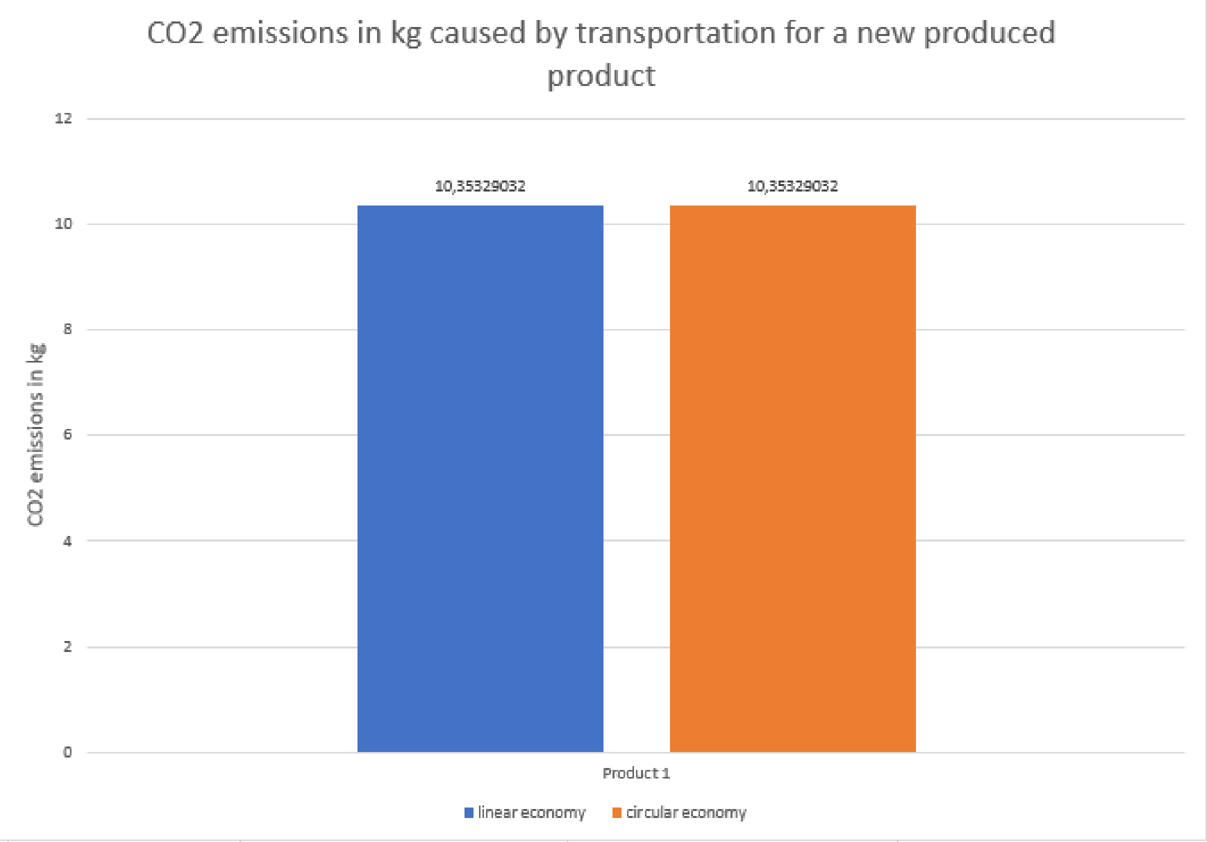

Figure 15: CO2 emissions in kg caused by transportation for a new produced product, (Author, 2021)

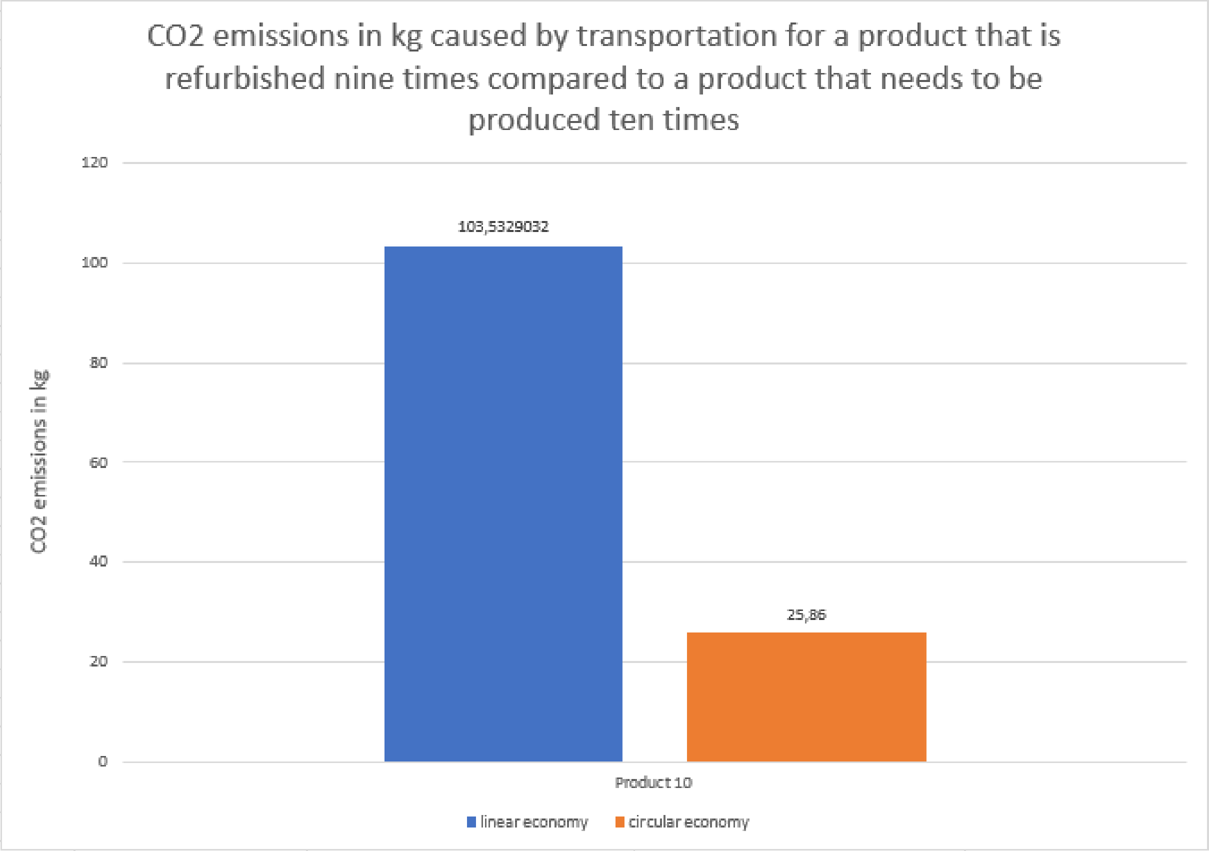

Figure 16: CO2 emissions in kg caused by transportation for a product that is refurbished nine times compared to a product that needs to be produced ten times, (Author, 2021)

6.2 Value Hill

As already displayed in the findings, the concept of the value hill demonstrates the values of the different stages in a clear overview. Furthermore, it displays how the circular economy is structured and how it works. The circular economy can help save costs and reduce resources and allows the products, compared to the linear economy, to stay at their highest level of value for as long as possible. On the other hand, the linear economy is usually sales orientated, and therefore, focussed on selling as many products as often as possible. Therefore, it would be contra-productive if the products stay at their highest level of value for as long as possible. The figure below displays the value hill of the linear economy. The pre-use side of the figure displays the creation of the products beginning with the extraction of the raw materials, the manufacturing, followed by the assembling of the products and finally, the retail to the users. With each step, value is added until the product is completed. When the product is retailed to the user, the product has reached its highest value. After that, the product's value becomes less, and it goes downhill on the post-use side. The products normally have a relatively short life span and are destroyed quickly afterwards to create new products.

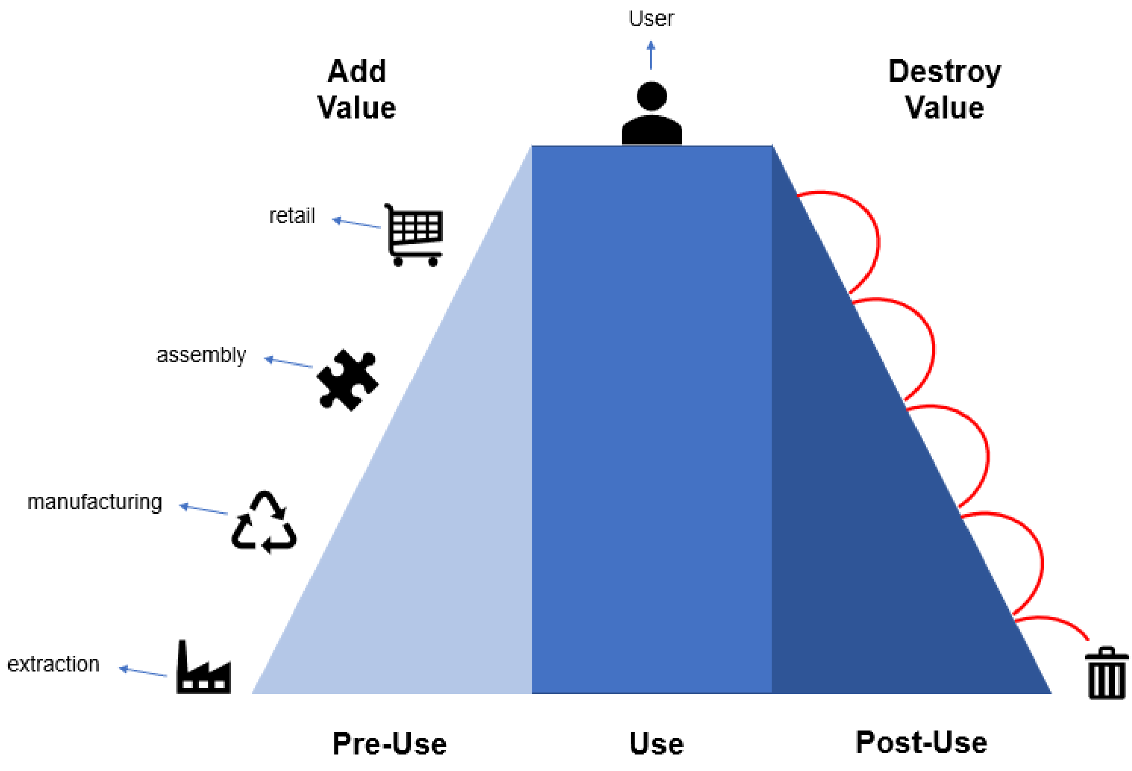

Figure 17: Value Hill linear economy, own illustration (NuoValente, 2016)

When looking at the value hill of the circular economy, on the other hand, it can be noticed that the waste of a product is not destroyed as fast as possible but used for the creation of other products. As already mentioned, the circular economy aims to maintain the highest value of the product as long as possible, or even, if possible, forever. Therefore, companies that follow the circular economy normally are willing to create more robust and long-lasting products than companies that follow the linear economy. As displayed in the figure below, the pre-use stage of the circular economy includes the same steps as the linear economy. With each step, the product adds value until it reaches its highest value in the use stage. To contribute that the products stay as long as possible in this stage, the best solutions are the repair and the maintenance of the product. If the product still reaches its end of life, the post-use stage begins, in which the product loses value with each step. Nevertheless, the post-use stage offers a lot of alternatives and benefits when used correctly. With reusing, refurbishing, remanufacturing and recycling, the used product flows directly back into the pre-use or even the use stage, which minimizes the costs and resources. Reusing or redistributing retain the most value on the product after the use stage itself. The refurbishment is the next step downhill, followed by remanufacturing and then recycling the product. That shows that recycling retains less value to the product than, for example, refurbishing the product. That is because when recycling a product, it needs to be torn apart and then remanufactured, while when refurbishing a product, only the last layer needs to be scrubbed off and cleaned up, and then the new layer sprayed on.

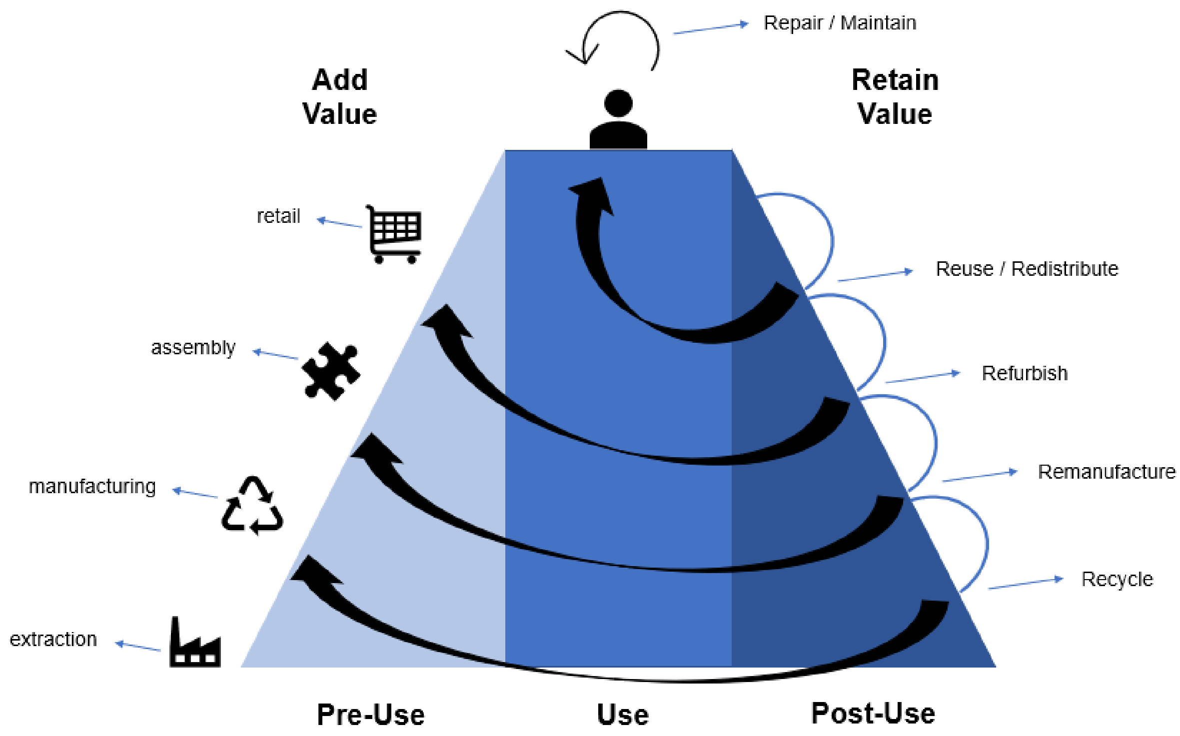

Figure 18: Value Hill circular economy, own illustration (NuoValente, 2016)

6.3 Environmental Product Declaration

As displayed in the findings, many companies use an Environmental Product Declaration to present the environmental performance of a product. The environmental product declaration, which is a standardized tool based on a life cycle analysis and aims to present the environmental performance of a product, is used by most companies for marketing benefits. Furthermore, it presents the product and the life cycle as well as the involved stages to the customers. Therefore, it clearly demonstrates the involved stages in the linear economy compared to the circular economy. The Environmental Product Declaration of the linear economy consists of five stages separated again in single steps. The stages are the product stage, the construction stage, the use stage, the end of life stage and the last stage, which displays the benefits and loads beyond the system boundary, so, mainly the benefits generated by reusing, recovering and recycling the resources in between the life cycle. Chapter 6.2 demonstrated that a product produced in a circular economy follows the same steps as a product produced in a linear economy to reach its highest value in the use stage. Therefore, the Environmental Product Declaration of the circular economy consists of the same five stages. Nevertheless, the end of life stage differs from the same stage in the linear economy. The reason for that is the different utilization of the used resources. While the end of life stage of the linear economy concentrates on destroying the used product as fast as possible, the end of life stage of the circular economy focusses on the 3R´s, reducing, reusing and recycling of the used resources so that they flow directly back into the pre-use or even the use stage. Furthermore, as already stated in chapter 6.2, the linear economy's use stage is usually shorter than the use stage of the circular economy, as the linear economy focuses on selling as many products as possible. In contrast, the circular economy concentrates on keeping the products as long as possible in the use stage. Moreover, the benefits and loads beyond the system boundary are more lucrative within the circular economy, as it focuses on reusing, recovering and recycling the used resources. The figure below displays the life cycles of the two economies. Furthermore, it displays the life cycle of the circular economy after the end of the product´s life, and the first refurbishment is done. Therefore, it can be noticed that the first two stages, the product stage and the construction stage, are not required anymore as the product is already produced and just needs to be refurbished. The other three stages remain the same.

	Environmental Product Declaration (EPD)																
	Interior Product Life Cycle Information																Supplementary Information beyond the interior Life Cycle
Linear Economy	A1-A3 Product Stage			A4-A5 Construction Stage		B1-B7 Use Stage							C1-C4 End of Life Stage				D Benefits and Loads beyond the system boundry
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Raw Material Supply	Transport	Manufacturing	Transport	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational Water use	De-construction	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
Circular Economy	A1-A3 Product Stage			A4-A5 Construction Stage		B1-B7 Use Stage							C1-C3 End of Life Stage				D Benefits and Loads beyond the system boundry
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3		D
	Raw Material Supply	Transport	Manufacturing	Transport	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational Water use	Transport	Refurbishment	Transport		Reuse-Recovery-Recycling-potential
Circular Economy (after the first refurbishment)						B1-B7 Use Stage							C1-C3 End of Life Stage				D Benefits and Loads beyond the system boundry
						B1	B2	B3	B4	B5	B6	B7	C1	C2	C3		D
						Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational Water use	Transport	Refurbishment	Transport		Reuse-Recovery-Recycling-potential

Table 8: Environmental Product Declaration, (Author, 2021)

6.4 Material Circularity Index

After the findings were discussed in chapter 5.6, the material circularity index can be analysed. The material circularity index is a useful tool to calculate and demonstrate the percentage of the raw material usage of a product, which is reused or recycled. Therefore, the calculated number can be used to compare it with other products or other materials or other techniques. Furthermore, it can be used to identify if a particular product is more circular than it used to be and also will it be more circular in the future. Nevertheless, the findings of the interviews demonstrated that it could be extended to receive all relevant numbers and data required to fulfil the indicators and calculate the material circularity index of the desired product. Therefore, the findings of the interviews couldn't collect all relevant numbers and data, as they weren't available. Nevertheless, the findings of the interviews have brought many assumptions regarding the material circularity index. The table below compares the material circularity index of different furniture produced with different procedures. The first one is a standard furniture produced by following the concept of the linear economy. As no recycled or reused materials are used to produce this furniture, the circularity index is 0%. The second one is a CooLoo furniture of similar dimensions as the standard furniture. When it is first produced, it has a circularity index of 10%. The next one displays the same furniture, after it is used and then refurbished. It has a circularity index of 95,5%. The following one displays a chair called "Moroso Fjord", which is prepared with a standard refurbishment. It has a circularity index of 80,2%. The same product prepared with the CooLoo refurbishment has a circularity index of 92,8%.

Furniture:	**Circularity Index:**
Standard Furniture 	**0%**
CooLoo Furniture (New)	**10%**

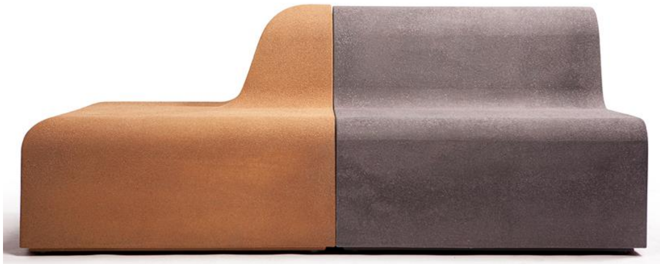	
CooLoo Furniture (Refurbished) 	**95,5%**
Moroso Fjord (Standard Refurbishment) 	**80,2%**
Moroso Fjord (CooLoo Refurbishment) 	**92,8%**

Table 9: Material Circularity Index Comparison. (Author,2021)

The two tables below include all relevant indicators which are required as well as the material circularity indicator. All indicators were filled with numbers that are speculated, with the aim to demonstrate the differences between the two figures. The first figure demonstrates one of CooLoo´s products when it is produced in the first place, considering all relevant steps as mentioned in chapter 6.2, which are the extraction of the raw materials, manufacturing, assembling and retailing to the user. The second figure demonstrates one of Cooloo´s products after the first refurbishment is done. Therefore, the previous steps as the raw material extraction and the manufacturing are not required anymore. Furthermore, a significant fraction of the product can be used again or remains the same, as the product gets refurbished after the used stage instead of being destroyed and thrown away. When the used product reaches its end of life, it gets transported back to CooLoo´s manufacturing site, where it gets refurbished. Therefore, only the top layer of the product, which is the finishing, gets cleaned up, and then the new finishing gets sprayed on the product. The refurbishment has an enormous impact on the outcome of the material circularity index of CooLoo´s product, as nearly the whole product remains the same or can be used again. The first figure below has an outcome of 0.1, which implements that 10 % of the fraction of the product is reused or recycled. On the other hand, the second figure has an outcome of 0.955, which implements that 95.5% of the fraction of the product is reused or recycled. The reason for that is that when the product is produced in the first place, the author assumes that no resources are reused (FU=0). In contrast, when the product gets refurbished, the author assumes that 95% of the resources are reused (FU=0.95), as the findings of the interviews showed that nearly the whole product remains the same.

Material Circularity Index CooLoo new Product

M	Mass of a product	100
FR	Fraction of mass of a product's feedstock from recycled sources	0
FU	Fraction of mass of a product's feedstock from reused sources	0
FS	Fraction of a product's biological feedstock from Sustained Production. Biological material that is recycled or reused is captured as recycled or reused material, not biological feedstock.	0
V	Material that is not from reuse, recycling or, for the purposes of this methodology, biological materials from Sustained Production.	100,0
CC	Fraction of mass of a product being collected to go into a composting process	0
CE	Fraction of mass of a product being collected for energy recovery where the material satisfies the requirements for inclusion.	0
CR	Fraction of mass of a product being collected to go into a recycling process	0
CU	Fraction of mass of a product going into component reuse	0
EC	Efficiency of the recycling process used for the portion of a product collected for recycling	0
EE	Efficiency of the energy recovery process for biological materials satisfying the requirements for inclusion.	0
EF	Efficiency of the recycling process used to produce recycled feedstock for a product	1
BC	The carbon content of a biological material, by default a value of 45% is used unless supported by evidence to the contrary.	0,45
W	Mass of unrecoverable waste associated with a product	100
WO	Mass of unrecoverable waste through a product's material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable	100
WC	Mass of unrecoverable waste generated in the process of recycling parts of a product	0
WF	Mass of unrecoverable waste generated when producing recycled feedstock for a product	0
F(X)	Utility factor built as a function of the utility X of a product	0,9
X	Utility of a product	1
L	Actual average lifetime of a product	10
Lav	Average lifetime of an industry-average product of the same type	10
U	Actual average number of functional units achieved during the use phase of a product	10
Uav	Average number of functional units achieved during the use phase of an industryaverage product of the same type	10
Ni	Normalising factor used to aggregate product-level MCIs using a weighted average approach; the index i refers to a specific product range or department	1
LFI	Linear Flow Index	1
MCIp	Material Circularity Indicator of a product	0,1

Table 10: Material Circularity Index CooLoo new Product, own illustration (Ellen MacArthur Foundation, 2019) (Inside Inside EPD Database, 2020)

Material Circularity Index CooLoo refurbished Product

M	Mass of a product	100
FR	Fraction of mass of a product's feedstock from recycled sources	0
FU	Fraction of mass of a product's feedstock from reused sources	0,95
FS	Fraction of a product's biological feedstock from Sustained Production. Biological material that is recycled or reused is captured as recycled or reused material, not biological feedstock.	0
V	Material that is not from reuse, recycling or, for the purposes of this methodology, biological materials from Sustained Production.	5,0
CC	Fraction of mass of a product being collected to go into a composting process	0
CE	Fraction of mass of a product being collected for energy recovery where the material satisfies the requirements for inclusion.	0
CR	Fraction of mass of a product being collected to go into a recycling process	0
CU	Fraction of mass of a product going into component reuse	0,95
EC	Efficiency of the recycling process used for the portion of a product collected for recycling	0
EE	Efficiency of the energy recovery process for biological materials satisfying the requirements for inclusion.	0
EF	Efficiency of the recycling process used to produce recycled feedstock for a product	1
BC	The carbon content of a biological material, by default a value of 45% is used unless supported by evidence to the contrary.	0,45
W	Mass of unrecoverable waste associated with a product	5
WO	Mass of unrecoverable waste through a product's material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable	5
WC	Mass of unrecoverable waste generated in the process of recycling parts of a product	0
WF	Mass of unrecoverable waste generated when producing recycled feedstock for a product	0
F(X)	Utility factor built as a function of the utility X of a product	0,9
X	Utility of a product	1
L	Actual average lifetime of a product	10
Lav	Average lifetime of an industry-average product of the same type	10
U	Actual average number of functional units achieved during the use phase of a product	10
Uav	Average number of functional units achieved during the use phase of an industryaverage product of the same type	10
Ni	Normalising factor used to aggregate product-level MCIs using a weighted average approach; the index i refers to a specific product range or department	1
LFI	Linear Flow Index	0,05
MCIp	Material Circularity Indicator of a product	0,955

Table 11: Material Circularity Index CooLoo refurbished Product, own illustration (Ellen MacArthur Foundation, 2019) (Inside Inside EPD Database, 2020)

The table below displays the calculation of the material circularity index of the "Moroso Fjord" prepared with a standard refurbishment. Therefore, the used leather of the chair is torn off and then replaced by new leather, which is not reused or recycled. The rest of the chair can be reused. The weight of the leather is 22% of the whole chair, from which one includes that 78% of the product´s weight can be reused. This standard refurbishment has a circularity index of 80,2%.

<u>Material Circularity Index Moroso Fjord Standard Refurbishment</u>

M	Mass of a product	100
FR	Fraction of mass of a product's feedstock from recycled sources	0
FU	Fraction of mass of a product's feedstock from reused sources	0,78
FS	Fraction of a product's biological feedstock from Sustained Production. Biological material that is recycled or reused is captured as recycled or reused material, not biological feedstock.	0
V	Material that is not from reuse, recycling or, for the purposes of this methodology, biological materials from Sustained Production.	22,0
CC	Fraction of mass of a product being collected to go into a composting process	0
CE	Fraction of mass of a product being collected for energy recovery where the material satisfies the requirements for inclusion.	0
CR	Fraction of mass of a product being collected to go into a recycling process	0
CU	Fraction of mass of a product going into component reuse	0,78
EC	Efficiency of the recycling process used for the portion of a product collected for recycling	0
EE	Efficiency of the energy recovery process for biological materials satisfying the requirements for inclusion.	0
EF	Efficiency of the recycling process used to produce recycled feedstock for a product	1
BC	The carbon content of a biological material, by default a value of 45% is used unless supported by evidence to the contrary.	0,45
W	Mass of unrecoverable waste associated with a product	22
WO	Mass of unrecoverable waste through a product's material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable	22
WC	Mass of unrecoverable waste generated in the process of recycling parts of a product	0
WF	Mass of unrecoverable waste generated when producing recycled feedstock for a product	0
F(X)	Utility factor built as a function of the utility X of a product	0,9
X	Utility of a product	1
L	Actual average lifetime of a product	10
Lav	Average lifetime of an industry-average product of the same type	10
U	Actual average number of functional units achieved during the use phase of a product	10
Uav	Average number of functional units achieved during the use phase of an industryaverage product of the same type	10
Ni	Normalising factor used to aggregate product-level MCIs using a weighted average approach; the index i refers to a specific product range or department	1
LFI	Linear Flow Index	0,22
MCIp	Material Circularity Indicator of a product	0,802

Table 12: Material Circularity Index Moroso Fjord Standard Refurbishment, own illustration (Ellen MacArthur Foundation, 2019) (Inside Inside EPD Database, 2020)

On the other hand, the table below displays the calculation of the material circularity index of the "Moroso Fjord" prepared with the CooLoo refurbishment. Therefore, the used leather of the chair is also torn off but then replaced with recycling materials. The weight of the recycling materials sums 14% of the product. Furthermore, water-based glue is used to attach the recycling material to the chair. The weight of the water-based glue totals 4,2% of the product. The water-based glue is not reused or recycled. The remaining 81,8% of the weight of the product can be fully reused. This CooLoo refurbishment has a circularity index of 92,8%.

Material Circularity Index Moroso Fjord CooLoo Refurbishment

M	Mass of a product	100
FR	Fraction of mass of a product's feedstock from recycled sources	0,14
FU	Fraction of mass of a product's feedstock from reused sources	0,818
FS	Fraction of a product's biological feedstock from Sustained Production. Biological material that is recycled or reused is captured as recycled or reused material, not biological feedstock.	0
V	Material that is not from reuse, recycling or, for the purposes of this methodology, biological materials from Sustained Production.	4,2
CC	Fraction of mass of a product being collected to go into a composting process	0
CE	Fraction of mass of a product being collected for energy recovery where the material satisfies the requirements for inclusion.	0
CR	Fraction of mass of a product being collected to go into a recycling process	0,14
CU	Fraction of mass of a product going into component reuse	0,818
EC	Efficiency of the recycling process used for the portion of a product collected for recycling	0
EE	Efficiency of the energy recovery process for biological materials satisfying the requirements for inclusion.	0
EF	Efficiency of the recycling process used to produce recycled feedstock for a product	1
BC	The carbon content of a biological material, by default a value of 45% is used unless supported by evidence to the contrary.	0,45
W	Mass of unrecoverable waste associated with a product	11,2
WO	Mass of unrecoverable waste through a product's material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable	4,2
WC	Mass of unrecoverable waste generated in the process of recycling parts of a product	14
WF	Mass of unrecoverable waste generated when producing recycled feedstock for a product	0
F(X)	Utility factor built as a function of the utility X of a product	0,9
X	Utility of a product	1
L	Actual average lifetime of a product	10
Lav	Average lifetime of an industry-average product of the same type	10
U	Actual average number of functional units achieved during the use phase of a product	10
Uav	Average number of functional units achieved during the use phase of an industryaverage product of the same type	10
Ni	Normalising factor used to aggregate product-level MCIs using a weighted average approach; the index i refers to a specific product range or department	1
LFI	Linear Flow Index	0,079793
MCIp	Material Circularity Indicator of a product	0,928187

Table 13: Material Circularity Index Moroso Fjord CooLoo Refurbishment, own illustration (Ellen MacArthur Foundation, 2019) (Inside Inside EPD Database, 2020)

6.5 Environmental Footprint

After the findings were presented in 6.7, the environmental footprint can be analysed. The figure below shows the environmental footprint of the finishing, which is used for a coating surface covering 8 m² of CooLoo´s products. The environmental footprint arises out of the environmental costs of the seven involved environmental indicators and sums up to a value of 0.219846986896€. The environmental costs arise by multiplying the relevant cost per unit with the relevant quantity per unit. As analysed in the previous research, the finishing is the one of the four main supplied raw materials, which is used for the refurbishment and, therefore, has an essential impact on the circular economy of CooLoo´s products and the outcome of the environmental footprint. While the other three supplied raw materials, the polyurea, the polyether foam and the webbing, are not required for the refurbishment and therefore only used for the first manufacturing of the product, the finishing is used not only for the first manufacturing but also for each refurbishment that will be performed. Therefore, the environmental footprint of the finishing has the most decisive impact on the overall environmental footprint of the product. So, even if the environmental footprint of the finishing would be less than the environmental footprint of the other three supplied raw materials, it must be considered that the finishing has an impact each time the product gets refurbished. In comparison, the other three materials only have an impact once. When looking at the findings in chapter 5.7, one can see that standard furniture produced with the concept of the linear economy, which has similar dimensions as the CooLoo product, has an environmental footprint of 3,14€. (Inside Inside, 2020) Considering that the CooLoo product has a similar environmental footprint when produced in the first place, one can say that the environmental footprint can be reduced many times over as the refurbishment has an environmental footprint of only 0,22€.

Environmental Indicators	Cost per Unit:	Quantity per Unit:	Environmental Cost:	
Abiotic depletion potential for non-fossil resources (kg Sb eq.)	0,16 €	0,0000151393	**0,000002422288 €**	
Abiotic depletion potential for fossil resources (MJ)	0,00007696 €	56,42765	**0,004342671944 €**	
Acidification potential of soil and water (kg SO_2 eq.)	4,00 €	0,01347792	**0,05391168 €**	
Depletion potential of the stratospheric ozone layer (kg CFC-11 eq.)	30,00 €	0,0000002718288	**0,000008154864 €**	
Global warming potential (kg CO2 eq.)	0,05 €	2,638328	**0,1319164 €**	
Eutrophication potential (kg $(PO_4)^{3-}$ eq.)	9,00 €	0,003250612	**0,029255508 €**	
Formation potential of tropospheric ozone kg (C_2H_4)	2,00 €	0,000205075	**0,0004101498 €**	
			0,219846986896 €	**Environmental Footprint**

Table 14: Environmental Footprint Calculation, own illustration (Inside Inside EPD Database, 2020) (Ozturk and Dincer, 2019) (Ros-Dosdá, et al., 2019)

7. Conclusion

This present chapter displays all relevant findings of this research project. Furthermore, it presents the limitations, as well as recommendations for future research regarding the research done in this project.

7.1 Practical implications

This research project aimed to analyse how, in the age of numbers and data, CooLoo´s technologies and products benefit the circular economy, CO_2 reduction, kJ use, climate and UN Sustainable development goals by comparing their technologies and products with the current standards in the market. Therefore, the author analysed relevant academic literature and conducted five expert interviews with both experts from the company CooLoo and direct raw material suppliers of CooLoo.

7.1.1 Transportation

The discussion in chapter 6.1 regarding the transportation used by CooLoo and CooLoo´s suppliers revealed interesting evidence. It pointed out the main differences in a company's transportation when following either the concept of the linear or the circular economy. One can say that CooLoo benefitted their product transportation by following the concept of the circular economy. When considering that one of CooLoo´s products can be refurbished at least ten times, the km covered for the transportation of one product can be reduced by a factor of over four. The same applies to the CO_2 emissions in kg caused by transportation for one product and the Global Warming Potential, which illustrates the impact on the environmental Footprint in € caused by the transportation.

7.1.2 Value Hill

The findings of the interview of one of CooLoo´s experts in chapter 5.4 stated the importance of the “Value Hill”, which demonstrates the benefits of the circular economy. The “Value Hill” highlights that the circular economy makes use of reusing, refurbishing, remanufacturing and recycling the used products, which allows the used resources to flow directly back into the pre-use or even the use stage. Therefore, the circular economy can help save costs and reduce resources and allow the products, compared to the linear economy, to stay at their highest level of value for as long as possible. Furthermore, the “Value Hill” states that even though the recycling process is a relevant part of the circular economy, it is still not the most sustainable process, as when recycling a product, it needs to be torn apart and then remanufactured, while when refurbishing a product, only the last layer needs to be scrubbed off and cleaned up and then the new layer sprayed on.

7.1.3 Environmental Product declaration

The analysis in chapter 6.3 demonstrates the benefits of applying the circular economy to the environmental product declaration. An environmental product declaration is a standardized tool based on a life cycle analysis and aims to present the environmental performance of a product. Based on the analysis, one can say that the implication of the circular economy concept has an impact on the environmental product declaration. As the environmental product declaration displays the life cycle of a product, it can be noticed that the implication of the circular economy shortens the whole life cycle of a product, and therefore, fewer steps are required. In the case of CooLoo, it can be stated that the first two stages, the product stage and the construction stage, are not required anymore as the product is already produced and just needs to be refurbished. The other three stages remain the same. This again results in the fact that less raw materials, fewer manufacturing processes and less transportation are required.

7.1.4 Material Circularity Index

The analysis in chapter 6.4 demonstrates that the material circularity index is a useful tool to calculate and illustrate the percentage of the raw material usage of a product, which is reused or recycled, and then, for example, to compare it with other products or other materials or other techniques and consider which is the most suitable option for a company. Furthermore, the analysis revealed that if a company follows the circular economy concept, it can reach a higher percentage in the material circularity index and, therefore, make the use of resources more circular than when following the concept of the linear economy.

7.1.5 Environmental Footprint

Next to the Material Circularity Index, another useful tool is the calculation of the Environmental Footprint, which is analysed in chapter 6.5. Therefore, the seven environmental indicators stated in chapter 4.2 are required and need to be analysed. Due to the analysis, one can say that the circular economy has an impact on the outcome of the overall environmental footprint of a product. When looking at CooLoo´s products, it can be stated that the use of the circular economy reduces the environmental footprint. As for the refurbishment, only one of the four main resources, the finishing, is required. As the use of each resource impacts the environmental footprint, this means that it can be minimized. On the other hand, following the linear economy requires taking all four resources into account each time a product gets produced.

7.1.6 Recommendations

Based on the conducted analysis, the author can draw several conclusions for the company CooLoo as well as other companies that consider following or already following the concept of the circular economy. The previous analysis showed that the Environmental Product Declaration, Material Circularity Index and the Environmental Footprint are useful tools to demonstrate information and data and display the benefits of the used concept of the circular economy. Therefore, CooLoo should consider integrating these calculations into their business to compare the outcome with competitors and also to present the benefits of the product to their customers as a sustainable case towards the relevant market. Furthermore, these calculations can be used to identify which of the used materials have the most benefits regarding CooLoo´s circularity goals. Thereby, they can also identify the materials with the worst outcome and can consider changing or improve these. Future research topics will be explained in chapter 7.2.

7.1.7 Summary

Many conclusions were drawn regarding the aim of this research project to analyse how, in the age of numbers and data, CooLoo´s technologies and products benefit the circular economy. One can say that the implementation of the circular economy concept used by CooLoo has positive impacts on transportation, CO2 emissions, the life cycle of a product, the value of a product and the circularity of a product. Furthermore, the circular economy can support waste and cost reduction and fully utilise the capacity and use of the resources. Therefore, the circular economy is a supportive concept with many benefits on the economy of each company that is willing to use this concept or that already use it, such as CooLoo. This research has shown, with the used methodology and collected data, that CooLoo´s circular technologies strongly benefit the furniture industry within the circular economy. This is clearly shown in the previous chapters and specifically the circularity index comparisons.

7.2 Limitations

After the research is conducted, it needs to be mentioned that there were a few limitations the researcher had to deal with. First of all, the primary research conducted as a mono method qualitative study in the form of interviews had a limited number of participants as it included only experts from the company CooLoo itself and the suppliers of CooLoo and participants. They have a significant Know-How for the research relevant resources polyether foam, webbing, polyurea and the finishing. Furthermore, not all relevant participants were available or willing to be part of this research. Therefore, only the Know-How and the statements of the voluntarily available participants have been incorporated into this research. Another limitation is that the secondary research was conducted with academic articles and books, which are available in German and English, as the researcher is only fluent in these two languages. Moreover, another limitation is that, in the period in which this research was carried out, the covid 19 pandemic was present and led to several implications. One of them is that all the interviews conducted had to be done online, and the researcher couldn´t talk to the participants in person, which could lead to a lack of interaction. The same implication was present for the meetings with the dissertation supervisor and the company supervisor. Finally, one limitation is that this research was conducted in a limited amount of time. All in all, it can be said that this dissertation was conducted to the best of the researcher's knowledge.

7.3 Future research

Based on the analysis and conclusion of this research project, further interesting ideas were discovered, which could be investigated in further research. First of all, it could be interesting to concentrate on the environmental footprint calculations and the material circularity index. As the data collection is very time-consuming, these could be the topics for further research, gather more relevant data and data of a different product, and compare them. As CooLoo only has four main suppliers, it could also be interesting to collect the data of companies with many suppliers, which allows a higher rate of interview participants and a better comparison between them. Another interesting research topic could be to analyse if the circular economy is possible to work efficiently over long distances, for example between Europe and Asia, as in today's the trade between different continents is very common and many supply chains are crossing borders and continents. Furthermore, it could be interesting to investigate if the circular economy can compete with other economies if you look at the costs of the products and then investigate if the circular economy could also be successful in third world countries.