Measuring sustainability in circular startups: the Waterweg case study

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WATERWEG

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Layman Summary

As a society, we have been developing our economy in a way that is unsustainable. Luckily, new ways of doing business have developed. One of them is the circular economy (CE). In the circular economy, waste from one business or product is seen as a resource for another. In this way, we can limit how many new resources we take from the environment. Waterweg is a company that does exactly this by using dredge sediment as a resource. Dredge sediment is the sludge that is taken out of waster-ways during maintenance. This is a really big waste stream in the Netherlands as there are a lot of rivers and canals that require regular maintenance. Waterweg collects this waste stream and uses it to make a material that can replace concrete pavement tiles. As concrete is also not a sustainable business, with their solution Waterweg can solve two problems: the problem of dredge and the problem of concrete. However, in order to be able to get clients and projects, Waterweg needs to show with real
numbers and analyses that they are more sustainable than their competition. This can be done by measuring the environmental impact of the product, so how much negative emissions like CO2 are released during the production process of the tiles. This can be measured using a framework known as the life cycle assessment (LCA). The LCA includes all the emissions associated with the production of the product, and those emissions can be combined into one single score that describes the overall sustainability of the product known as the environmental cost indicator (ECI). The LCA of the tiles analysed in this research showed that compared to regular concrete tiles, the Waterweg tiles perform 30% better in both CO2 emissions and ECI. However, the process of making the LCA was very difficult. Therefore, a parallel research was conducted to try and see if the LCA is the best way to measure sustainability for startups that work in the CE. After many interviews with startups, it became clear that they all face similar struggles when wanting to make an LCA. Some of those struggles are the lack of data to be able to do the analysis, the lack of resources like money and time to do it themselves or outsource it to an external company, and overall the uncertainty of what the startup will produce and how they will produce it in the future. Some experts in measuring impact were also interviewed, and they had similar difficulties when having to make LCA themselves for circular startups. However, startups often need to make LCAs to work with governments and clients, but they avoid it now because of the difficulty in making LCAs. The recommendations after this part of the research are for governments and big corporations to have less strict requirements for startups as well as to provide financial support or comparable resources to help those who want to calculate their LCA, and help them continuing to grow and develop

Abstract

Waterweg is a company that makes water passing pavement tiles out of dredge. Dredge is a big waste stream in the Netherlands. Traditional concrete tiles have very high environmental impacts. With their product, Waterweg can solve two problems at once by delivering a sustainable and durable product that can replace concrete tiles. There are a lot of ways to measure sustainability, and the most common in construction is called life cycle assessment (LCA). In this research, an LCA for the production of the tiles was analysed and compared to regular concrete tiles. The Waterweg's tiles performed better by roughly having 30% less CO2 emissions and a lower environmental cost indicator (ECI). Making an LCA for a startup in the circular economy (CE) is a difficult task. This research therefore was supplemented by interviews with startups and impact measurement experts to try to identify common problems experienced by both groups when making LCA analyses. Many commonalities could be found amongst the startups, such as lack of data, resources and problems with uncertainties of the production process and end-of-life (EoL) scenarios. The experts mentioned similar problems. Overall, it is clear that requiring early stage startup in CE to perform an LCA has the risk of hindering development for sustainability rather than helping it. Governmental and formal institutions should reconsider their requirement when it comes to this specific group by trying to be more lenient or helping the startups reach the requirements needed by means of resources and support.

Introduction

The problem of dredge: a large waste stream

Water management is one of the most developed fields in the Netherlands due to the large amount of waterways and shipping activities. Shipping vessels are getting larger, and this requires regular maintenance to increase the depth of rivers and canals to allow for boat traffic to proceed undisturbed. This activity is called dredging, companies dredge out the sediment from the bottom of waterways. In the Port of Rotterdam alone, 12-15 million metric cubes of dredge are taken out every year. [1] Roughly half of the dredging activities in the Netherlands are performed on sweet water. Of the total amount of sweet water dredge, the majority of it is polluted and cannot be directly applied to urban applications, such as increasing the height of roads. This dredge therefore has to be stored and processed in depots and/or landfills. The relative amounts of polluted and non polluted dredge for salt and sweet water dredge can be found on figure 1 [2]. It is clear that dredge is a multifaceted problem, and a solution needs to be designed to find (high) value applications for the large amount of dredge that is dredged out every year.

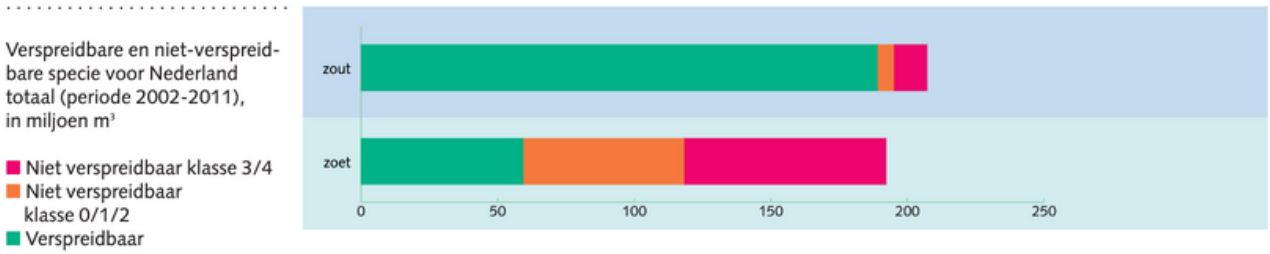

Figure 1: amount of non polluted dredge (verspreidbaar) and polluted dredge (niet verspreidbaar) coming out of salty and sweet water. [2]

Introduction to Waterweg and their product: making cities climate adaptive

Waterweg is a startup that was founded after one of the BlueCity circular challenges. In 2018, a team of young professionals, which included the two current founders Wies van Lieshout and Eva Aarts, were tasked by a municipality to come up with a profitable business model that would include dredge sediment as a resource. As previously discussed, dredge is a big waste stream in the Netherlands which currently holds a very low economic value. In six weeks time, the team came up with their business model that they still use to this day: using dredge as a resource to make a material replacement for concrete.

Their product is in the form of water passing pavement tiles. Having a water passing quality allows rainwater to pass through the gaps in the tile and seep into the ground where it can be momentarily stored and eventually is returned back into the urban ecosystem.

Due to climate change, the Netherlands is experiencing increasing rainfalls. By having water passing pavement tiles, floods can be prevented. This system is not only useful for flood prevention, but it has extra positive effects. Namely, storing water after heavy rain is a good strategy to combat the heat island effect of urban environments. Urban environments have been found to always have higher temperatures than their rural counterpart. This has a negative effect on the environment but also the health of urban citizens. With the increasing temperatures due to climate change, this problem is only destined to increase. The application of water passing pavement tile can be a way to combat this issue effectively and passively. The water that is temporarily stored under and in between the tiles after rainfall can evaporate and cool down the environment. [3]

Currently, Waterweg mostly works in collaboration with municipalities and water boards on small scale pilot projects. With these projects, their Minimum Viable Product (MVP) can be tested for usability, durability and to assess the market interest and potential. The current MVP is in the shape of a regular clinker stone, comparable to concrete clinker stones. There are already some possible designs for the final product, which will have the water passing qualities. However, this is still being tested via pilot projects as well. An example of a clinker stone and some of the possible final designs can be found in figure 2.

Figure 2: Left: clinker stone design. Right: possible designs for the final product. Taken from waterweg.co

To summarise, Waterweg is a startup that aims to resolve the issue of dredge, a large waste stream in the Netherlands, by making a replacement for concrete, an extremely polluting material. While doing so, they also create positive effects with their product such as flood and urban heat island effect prevention. Waterweg operates within BlueCity in Rotterdam, which is a model city for the circular economy, and Waterweg is a great example of how those principles can be applied.

The circular economy : a new way of doing business.

As a society, we see economic growth as one of the main measures of development. This mentality has caused humanity to operate outside the so called 'planetary boundaries', the safe operating space within which there are no negative environmental consequences for Earth. However, it is currently estimated that 4 out of the 7 measured planetary boundaries are being overshot, amongst which lies climate change. [4] Much unlike nature, humans have grown accustomed to a linear economy, the so-called take-make-waste process. However, it is becoming increasingly apparent that this process is not sustainable in the long run. Because of the economy of scale we live in, the true price of virgin materials is not reflected in the final products we buy. This has led humanity to keep on taking, completely disregarding the planetary boundaries of material resources. [5] The circular economy movement aims at rethinking this process and operating more sustainably and more attuned with the natural environment. Nature doesn't take more than it needs, recycles all materials and uses everything it does take, efficiently. [6] The main principle of CE is to design waste out of all systems, so that the waste generated is no longer considered waste, but instead becomes a resource for another process. This way, the value of any input and raw material is extended to the fullest. By operating within the framework of the CE, companies can still achieve economic growth without endangering the planet. [6]

Operating within the framework of the circular economy is one of the ways in which companies can try to be more sustainable. However, sustainability can be a difficult concept to measure. In the next sections some of the impact assessment methodologies used within CE are introduced and evaluated.

Impact assessment methodologies: are we actually sustainable?

Sustainability and CE have become a crucial topic, also highly regulated by policies and governmental agencies. This is a positive push in the right direction, however, the quantification of what is truly "sustainable" has become as much of an issue as being unsustainable in itself. What does it mean to be sustainable, how can it be quantified? These are questions that impact assessment methodologies attempt to answer. Following is a short review on known methodologies and their suitability for assessing sustainability for companies operating in the circular economy.

Life Cycle Assessment (LCA)

The most well known tool for measuring the environmental footprint of a company is the life cycle assessment (LCA). This tool has been developed by the international organisation for standardization (ISO), and thus provides a standard methodology for assessing the environmental impact of a product or service. There are a number of criticisms that could be made about LCAs. Generally, the methodology does not aid itself in comparing across different companies, let alone different industries. Despite its standardisation status, there are many choices that can still be made and thus change the final results, rendering two LCAs of the same product radically different depending on how they were conducted.

When considering the CE in particular, more specific pitfalls of the LCA methodology can be identified. For starters, LCAs have been developed to assess environmental footprint, thus measuring the negative impact, rather than evaluating a more holistic view on both negative and positive environmental effects. This is especially interesting when trying to make an LCA for CE products or services as there is no standard/good method to quantify and include the positive environmental effects within the LCA. This arises from the fact that LCAs have been developed to assess the take-make-waste linear economy, and are therefore not suited for the analysis of dynamic systems, such as those operating in the CE. Specifically, the methodology to decide on the allocation of the impacts of recycled resources is not sufficiently defined by the ISO when it comes to the case of CE products. In these systems, materials are not simply recycled back to virgin materials but are often re-used to make new products which have their own life cycle. How to account for this in CE system is still debated to this day. [7] Furthermore, when making an LCA one needs to define the functional unit (FU) of the system. This is a value which is supposed to define a certain function provided by the product/system which can be used to calculate the environmental impact of that unit across different stages. This can help in creating standardisation across companies and compare environmental impact of the same FU. However, when it comes to the CE, the standard FUs that are commonly used may not fully reflect the dynamism of the system, and thus not portray a complete picture. [8]

Material flow analysis (MFA)

Material flow analysis (MFA) is another assessment methodology used to assess the material processes of a large system. This method is mostly used to analyse steps of a life cycle related to materials and their flow, specifically to identify opportunities for waste management and availability of materials. Mostly, this method has been used to analyse material flow of larger systems, such as at a country or city level. Whilst MFA does serve itself for the purpose of analysing the results of implementing a CE (as the focus is on material flows), it does lack an analysis of the processes between each flow. This means that if one wanted to assess the environmental impact of a product's life cycle using this method, all aspects related to the processing or the in-use phase of a material wouldn't be taken into account, thus not giving a full picture of the sustainability of a particular CE strategy. For this reason, this method is not well adept for assessing companies of the CE which focus on business models like reusing, refurbishing or sharing. MFA therefore lacks the tools to take into account a full range of environmental and/or social impacts and is therefore, by itself, not enough to fully describe the environmental impact of a product or service. [8]

Cradle to Cradle (C2C)

Another approach that can be used to describe and analyse the sustainability of a company is by using the cradle to cradle (C2C) certification. Started as a philosophy to maximise positive impact on the environment, C2C became an actual certification that companies can acquire in order to showcase their sustainable practices and approach. In order to get the certification, companies need to be analysed on various impact categories: material health, material reutilisation, renewable energy, water stewardship and social fairness.

Looking at these categories, a parallel can be drawn between them and the previously mentioned impact methodologies. LCAs do take into account the hazardousness of a material in terms of chemical quality (material health), and take into account water and energy usage. MFA focuses on the analysis of material reutilisation, thus covering that portion of the categories. What is not included in either method is the inclusion of social fairness, a very important component of sustainability that is often overlooked but that is actually included in the C2C certification. However, there are a number of criticisms to be made about this framework as well. First of all, it is not an assessment method but rather a certification that can be achieved by a company. This certification is given out by a handful of institutes, resulting in a certification monopoly. As a result, the assessment for the certification can be biased in the measuring of the different categories. Literature shows that material health is by far the most important category that is taken into account, while the other categories are considered significantly less. Furthermore, there is no focus on the processes related to the use-phase of a product, leaving energy consumption out of the assessment. Further, from becoming a philosophy to an actual certification, criticism has been raised on C2C hindering innovation rather than fostering it, as companies focus on complying with the minimum requirements for achieving a C2C certification rather than improving their processes. [9] Finally, the C2C methodology is based on future scenarios and thus not focused on what is now, making the concept in itself (so not the certification) qualitative and thus unfit to quantify environmental impact. [10]

The need of Waterweg: measuring their impact

Waterweg is a business to business (B2B) and business to government (B2G) company, with most of their clients currently being governmental institutions. These parties are very interested in sustainability measurements. Especially in the construction industry, a very popular value is the Environmental Cost Indicator (ECI). The ECI is a single score value that gives information on the societal cost of a product, also known as the shadow cost, taking into account a variety of different environmental impacts. This value can be used to compare the environmental performance of products between manufacturers or across industries. The ECI can only be derived by performing an LCA analysis. Therefore, despite the clear shortcomings of the LCA methodology, the task for this internship was to analyse the life cycle of the tiles and calculate the emissions and the ECI of the current product, the clinker stones.

How to perform an LCA: general methodology

Through the LCA framework, the whole (or parts of) the life cycle of a company and their products can be analysed in a relatively standardised way. [11] This framework is internationally recognised and has been widely adopted, as was previously discussed. The method includes setting a goal, scope and functional unit for the analysis, collecting information on the product and process inputs and outputs during the inventory analysis, assessing the impact of these inputs and outputs, and finally interpreting the results. In the following paragraphs the LCA methodology is described and explained. A summary of the whole process is found in figure 3. [12] The first steps of the LCA are done to set the background information of the analysis. There are three components that need to be first defined before moving on to the actual analysis of emissions.

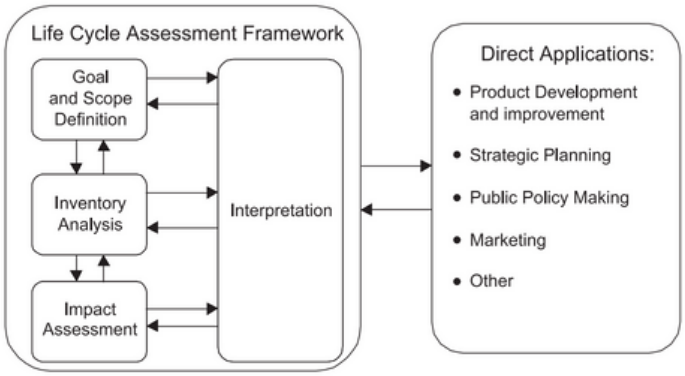

Figure 3: Phases and application of an LCA (based on ISO 14040, 1997) [12]

Firstly, the goal of the LCA needs to be formalised. Some companies might need an LCA to prove the compliance to certain standards, others might need it for applying to public procurement projects, while others might just want some insights into their emissions. Whatever the goal, it is important to properly think about it and describe it before moving on to the next phase of the LCA methodology, as the goal will inform how the analysis is carried out. [11]

The next step is to describe what kind of unit will be used to measure the emissions. This is a good way to bring extra normalisation in the data, as every emission of every step will be related to a specific unit of measurement. This unit of measurement is called Functional Unit. It is vital to describe the product in a quantitative way that properly describes the way one wants to assess the life cycle of a product. For example, the functional unit often includes a time component of what kind of function the product is performing over a period of time. This means that within the description of the functional unit, all materials and processes that are necessary for the product to perform its function need to be included in the assessment. [11]

Finally, the last background information that has to be finalised before diving into the analysis is the scope of the LCA. This essentially describes what part of the life cycle will be included, and which parts are excluded. In the construction industry specifically, there are different phases of a products life cycle which are described in different modules going from A to D [13]. These modules represent all steps in the life cycle of a product from manufacturing to recycling. A description of what each module includes is shown in figure 4.

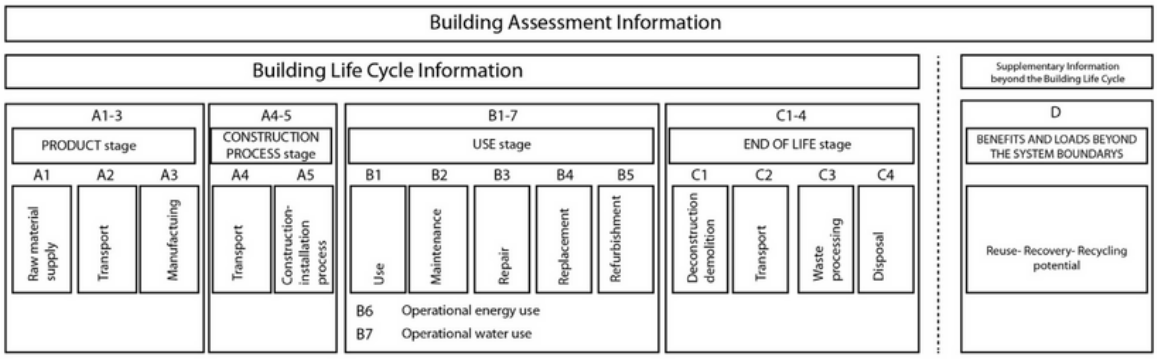

Figure 4: Building Assessment Modules for construction according to EN 15804-2012 [13]

There are different ways to do this. One kind of scope is the cradle to grave, this essentially describes all the processes within the life cycle of a product, so it will include everything from manufacturing up until the disposal of the product (modules A to C). Another way to analyse the scope is by doing a cradle to gate analysis, this will give information only on the production phase up until whichever phase the analyst decides to include (for example, including only module A1-3). Another way to limit the scope is by doing a gate to gate analysis, so for example from the moment the product is manufactured until it is placed or used. This specific analysis could be good if one wants to assess the emissions on transportation. Finally, in the circular economy one should also include recycling or reusing and therefore a new way of describing the scope is the cradle to cradle analysis. This, as the name suggests, includes analysing the whole life cycle of the product by going beyond the disposal phase and instead analyse how the parts of the unit can actually be recycled or reused elsewhere. [14] Doing this requires an additional module of computation known as module D, which describes the environmental benefits and burdens of a certain product from the secondary materials that can be derived at the end of life of a certain product. [15]

Once goal, functional unit and scope are finalised, the analyst can proceed to the inventory phase (LCI). This phase is essentially the data collection of all the processes and materials within the chosen scope that contribute to the environmental impact. Inputs and outputs are identified and quantified in relation to the functional unit. This includes raw materials, transport, manufacturing emissions, emissions during the use phase, and essentially everything that contributes to emissions has to be included. This can be a really time consuming step that requires a lot of time and iterations to get correctly, depending on the complexity of the scope or the product. [14]

When the inventory has been established, all the inputs of the system need to be translated into actual emissions during the impact assessment phase (LCIA). Emissions in an LCA can be classified using impact categories. Impact categories collect the relative impact of the different inputs and outputs from the inventory. Each category describes a specific environmental threat, for example climate change is expressed in global warming potential. In LCA for construction, the categories that are used to calculate the ECI and the units are shown in figure 5. This phase can be really complex depending on the availability of data on each input. In this phase the analyst needs to choose which impact categories to include in its analysis depending on the goal of the LCA. [14]

Finally, the results need to be interpreted critically. According to the ISO, this phase includes identifying shortcomings of the analysis in the LCI and the LCIA phase, evaluating how the whole study and analysis was conducted and giving conclusions and recommendations. As it is an iterative process, this interpretation phase can and should occur throughout the whole analysis, as it can help identify wrong assumptions early on in the analysis and/or it can inform changes that need to be made to the chosen parameters to improve the analysis. [14]

Impact category	Unit
Global warming	kg CO_2-eq
Ozone depletion	kg CFC-11-eq
Acidification of soil and water	kg SO_2-eq
Eutrophication	kg PO_4^{3-}-eq
Depletion of abiotic resources – elements	kg Sb-eq
Depletion of abiotic resources – fossil fuels	kg Sb-eq
Human toxicity	kg 1,4 DB-eq
Freshwater ecotoxicity	kg 1,4 DB-eq
Marine water ecotoxicity	kg 1,4 DB-eq
Terrestrial ecotoxicity	1,4 DB-eq
Photochemical oxidant creation (Smog)	kg C_2H_4

Figure 5: Impact categories included in the calculation of the ECI for the construction sector. [14]

Methodology and results: Life cycle assessment of Waterweg

Goal

The goal of the LCA was drafted together with the founders of Waterweg. This LCA is conducted to help Waterweg in their **communication about the (sustainable) impact of their product**. Namely, the LCA will be used and referred to during business and sales meetings, as well as for subsidy and grant applications, for which an estimate of the ECI is needed. Therefore, the goal of this LCA is to **quantify the impact of the product**, and do so in **relation to other building materials**. For the purposes of this study, the building material taken into account will be water passing pavement concrete tiles, in dutch known as "grasbetontegels". In previous research done by another intern, this was identified as the most comparable product to the tiles developed by Waterweg.

Scope

The scope of the LCA was informed by a number of reasons. First of all, the startup is still at an early stage. This means that the application of the product is at the moment limited to a few pilot studies. The full life cycle and end-of-life (EoL) possibilities have not been researched and evaluated yet. Therefore, modelling beyond the production phase would include a lot of assumptions. Secondly, as one of the goals is to compare the Waterweg's tiles to an existing product, the assumption is that the main difference between them will lie in the production phase, as the in-use phase (and possibly the EoL applications) will be very similar. Finally, the amount of open source databases for construction is limited, and mostly information on the production phase could be found. Therefore, the scope of this LCA is the production of the Waterweg's tiles. Namely, this is the A1 to A3 modules as seen on figure 6.

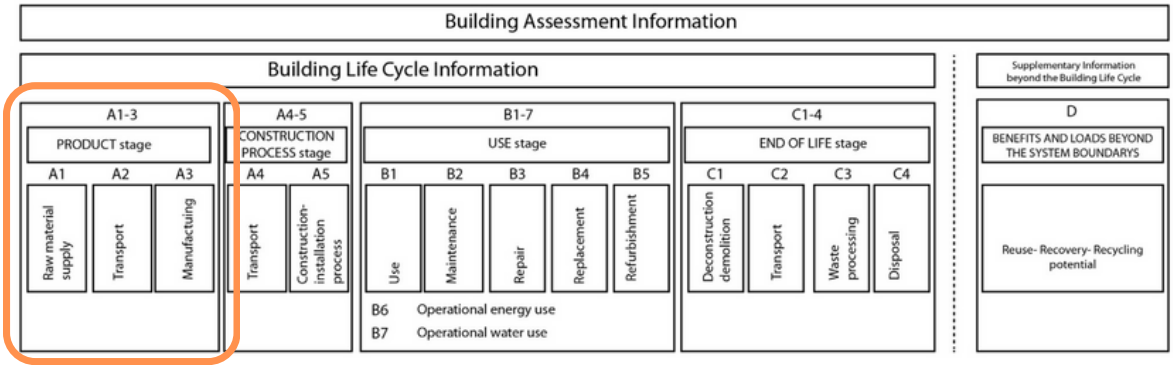

Figure 6: Scope of the LCA for the clinker stones of Waterweg. Adapted from [13]

Functional Unit

The functional unit was informed by looking at the available information of the 'grasbetontegels'. The A1 to A3 phase of the comparison material is calculated for the **production of 1 m3**. Because of this reason, the same functional unit was applied to the Waterweg tiles. This way, the two materials can be more accurately compared. In this functional unit the time component is missing, this was deliberately decided. The time scale of use would be important when assessing the use phase of the product (module B). However, since this is excluded from the scope, the functional unit was kept simple and without adding a time component.

Life Cycle Inventory (LCI)

The inventory was assessed during many iterations. The first iteration, which included the whole life cycle (from dredging to recycling/re-using) can be found in appendix A. However, during the project it was decided to limit the scope to only the production. Therefore, the input inventory for 1 m3 of Waterweg tiles was as follows:

	A1	A2	A3
Transport (Dredge)			
Electricity consumption for the production of 1 m3 of tiles			

Table 1: Inventory of the inputs of A1 to A3.

The calculations for how the amounts of raw materials and the electricity were derived can be found in appendix B.

Life Cycle Impact Assessment (LCIA)

The translation from these inputs into impact assessment category was done with two open source databases for construction materials: MRPI (Milieu relevante product informatie) and the National Milieu Database. During this phase it became clear that cement gave the biggest impact in all categories. For this reason, in this phase it was also decided to compare the use of CEM I, which is pure virgin cement, with CEM III, a type of cement composed between 40% and 90% by furnace slag, a byproduct of the iron industry [16]. The databases used per input can be found in appendix C.

For each tile composition (with CEM I or CEM III) the impact in each impact category was calculated. From these data, the Global Warming Potential (GWP) measured in kg CO2 eq. was derived for the different phases (A1 to A3) separately as well as cumulatively. The ECI was also calculated. The raw values can be found on appendix D. The same data analysis was done for the raw data of the comparison materials, namely grasbetontegels made with CEM I or CEM III, the raw data can be found on appendix E. The ECI was calculated according to the standard weights assigned per each impact category, shown in figure 7.

The calculations were performed on a Google sheet form which is accessible in the drive database of Waterweg. This was done in order to allow the founders to be able to adjust values in response to changes in the product's recipe or manufacturing process.

Impact category	**Unit**	**Weighting Factor** (€/ unit)
Global warming	kg CO_2-eq	0,05 €
Ozone depletion	kg CFC-11-eq	30,00 €
Acidification of soil and water	kg SO_2-eq	4,00 €
Eutrophication	kg PO_4^{3-}-eq	9,00 €
Depletion of abiotic resources – elements	kg Sb-eq	0,16 €
Depletion of abiotic resources – fossil fuels	kg Sb-eq	0,16 €
Human toxicity	kg 1,4 DB-eq	0,09 €
Freshwater ecotoxicity	kg 1,4 DB-eq	0,03 €
Marine water ecotoxicity	kg 1,4 DB-eq	0,0001 €
Terrestrial ecotoxicity	1,4 DB-eq	0,06 €
Photochemical oxidant creation (Smog)	kg C_2H_4	2,00 €

Figure 7: Impact categories included in the ECI and the weighing factor per category. [14]

Results and Interpretation

Global Warming Potential (GWP) of Waterweg's tiles

The global warming potential (GWP) is one of the most well known impact categories, as it measures the emissions in CO2 equivalents. It is popular because everybody is familiar with the concept of CO2 and it's easy for experts and laymen alike to understand the consequences of having a lower CO2 footprint. Therefore, calculating the GWP value can be useful for marketing and external communications.

Figure 8 shows the GWP of the clinker stones with CEM I or with CEM III. As it can be clearly seen, the footprint of CEM III is roughly 30% lower than that of virgin cement. This makes sense, as the production of CEM III takes advantage of a waste stream of another industry. Currently, the clinker stones are made using CEM I as a binder material. Replacing this with another product, for example CEM III, can dramatically reduce the footprint of the tiles. Following the same logic, replacing cement altogether with a more sustainable binder will unquestionably dramatically reduce the overall CO2 emissions of the product. The limitations of this analysis are also evident by looking at the graph. Firstly, one of the major components of the tiles, water, is not included. This is because the impact of water was not available online, therefore it could not be included. However, it can be assumed that the footprint of water in terms of CO2 equivalent is relatively low and possibly negligible compared to cement. Furthermore, the transport and the electricity consumption are both extremely low. This is because the current production process is based on small scale processes, which hardly use electricity. Once the production scales up and more machinery and steps are involved, these values are going to increase. Nonetheless, this is a good representation of the current CO2 emissions of the Waterweg tiles in the production process.

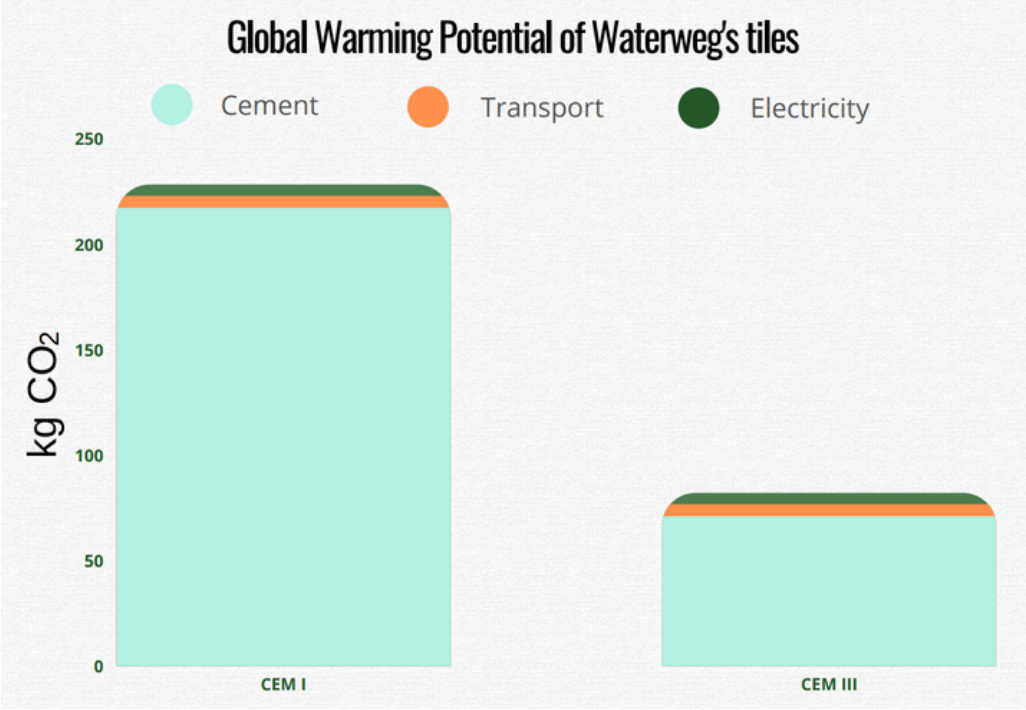

Figure 8: GWP in CO2 equivalent of A1 to A3 the Waterweg's tile with either CEM I or CEM III as binder.

The next analyses was done to compare the CO2 emissions between the Waterweg tiles and the reference materials, for CEM I and CEM III respectively. The results of this analysis can be found on figure 9. For both comparisons, grasbetontegel and Waterweg tile with CEM I and with CEM III, the tiles from Waterweg perform better. The CEM I Waterweg tiles have roughly 30% less emissions than the grasbetontegels, whereas the CEM III tiles emit roughly 50% less CO2 than the reference. The tiles from Waterweg contain less cement than regular concrete tiles, and the majority of the tile is composed of dredge which has an impact of 0. Concrete, other than binder and aggregates, is also often supplemented with additives which have a lot of impact. However, there are some limitations worth mentioning on this analysis. Firstly, due to the kind of data that is available, the emissions of the reference tile are given cumulatively for modules A1 to A3. This means that it is not possible to distinguish the impact of the different inputs: raw materials, transport and manufacturing process. So it is not possible to directly compare the impact of the raw materials between the different kinds of tiles, only speculations can be made. Furthermore, the reference tile includes water and packaging, which are not included in the Waterweg tiles. Water can be assumed to be nearly negligible, however, the packaging can have a more substantial impact that should be either included in the tiles for Waterweg, or deducted from the impact of the reference tile to make a fair comparison.

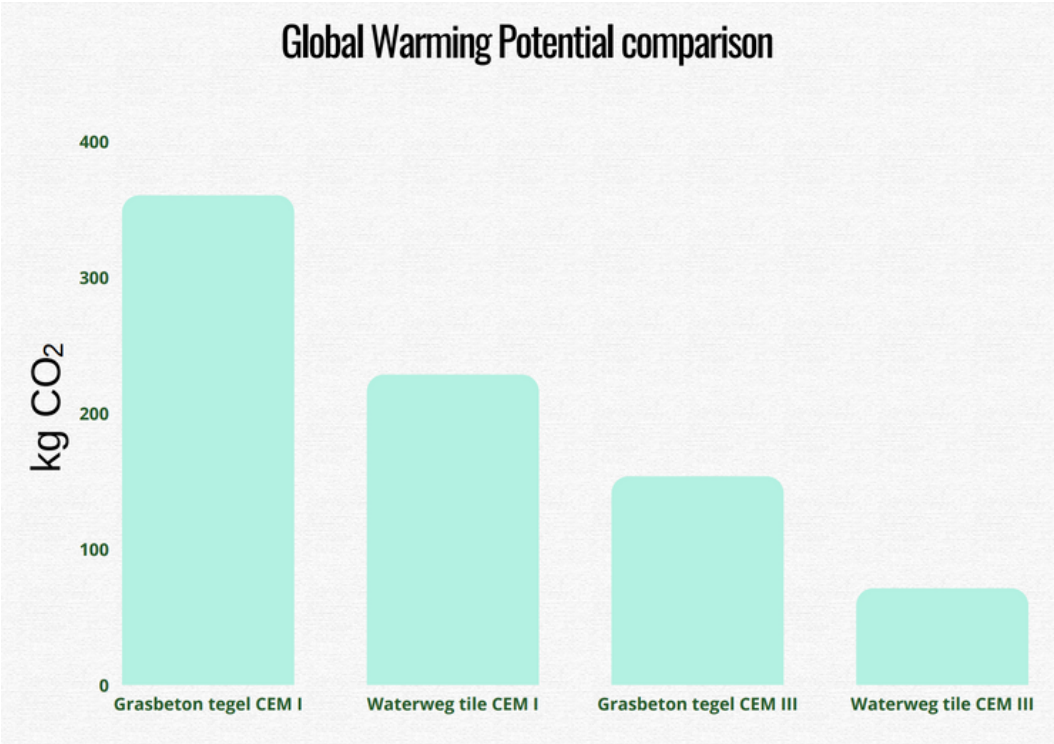

Figure 9: GWP of A1 to A3 of Waterweg's tiles compared to the reference tiles.

Enviornmental Cost Indicator (ECI) or Waterweg's tiles

The ECI was calculated as described in the methods section for both the reference tile and the Waterweg tiles. The results can be found in figure 10. From this graph, similar conclusions can be drawn as from the previous results. The ECI of the Waterweg's tiles is significantly lower than that of the reference tiles. The same limitations as previously described also apply for this value, as it is derived using the same data.

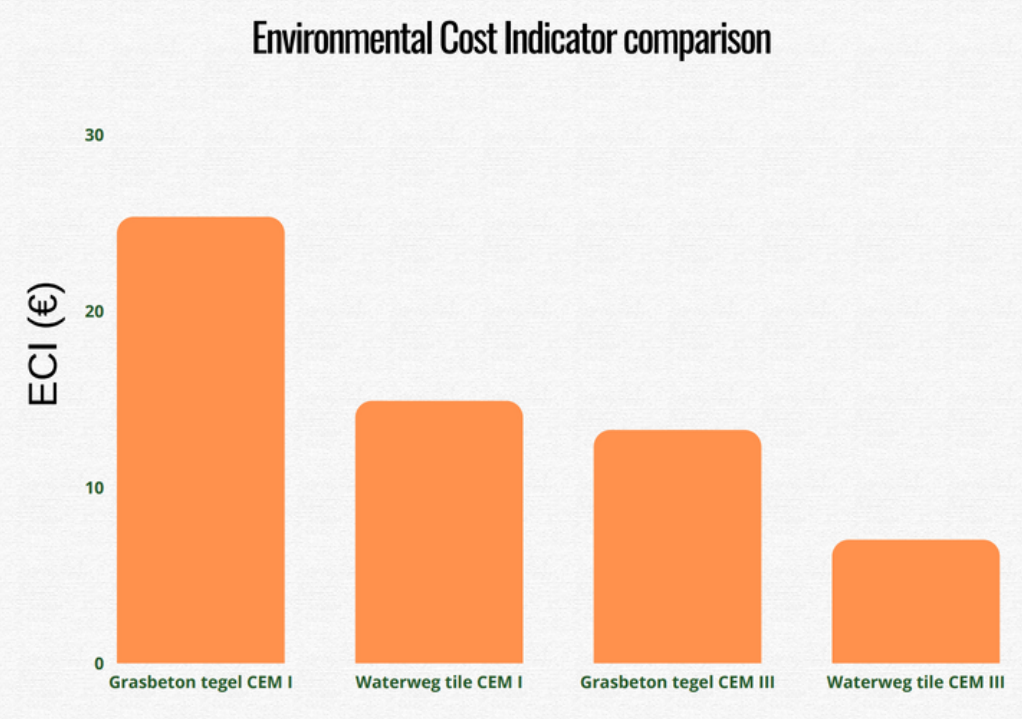

Figure 8: GWP in CO2 equivalent of A1 to A3 the Waterweg's tile with either CEM I or CEM III as binder.

Conclusion of LCA and recommendations

These values are estimates of the current production process of Waterweg. They give a limited overall insight into the emissions of the product, and therefore should be treated as such. There were three goals identified for this LCA: quantify the impact, comparing the emissions to a reference product and being able to externally communicate the results.

The impact of the tiles was quantified, but only of the production phase (modules A1 to A3). This was done due to limitations on availability of data and unknowns in the life cycle of the tiles. Furthermore, there were clear limitations on this data as the footprint of water was missing. Nonetheless, the results gave some insights into the use of cement and how that can be improved to lower the emissions. Namely, using CEM III in replacement to the currently used CEM I can easily lower the CO2 emissions by roughly 30%. It is clear that to continue trying lowering the impact, more attention should be given to the binder material. There are a number of sustainable binders that were researched by another intern to use instead of cement. However, the impact of these binders is often not disclosed as they are mostly newly developed materials.

Therefore, that could not be included in this analysis due to lack of data. It would be interesting to do so at a later stage, if these data was ever available.

The second goal was to compare the emissions to a reference material. The reference material chosen was the grasbetontegel given in emissions per cubic meter. Internally in the company, grasbetontegel is commonly used for comparison with the Waterweg tile. Therefore, this material was a good choice of reference. Furthermore, the emissions for the same production phase accounted for the Waterweg tile (A1 to A3) could be found on online databases. Therefore, it was possible to make a rough comparison of the two tiles. In the comparison for both the GWP and the ECI, the Waterweg tile performed better by at least roughly 30%. This is of course positive, as it is clear that the tiles from Waterweg are more sustainable than the grasbetontegels. However, aside from the computational limitations about data availability that were previously discussed, this comparison is still limited. It would be interesting to compare the Waterweg tiles to more concrete tiles, as well as other sustainable alternatives.

Finally, these results were meant to be used for official and unofficial external communication. I believe that for informal communication, to give indications on the performance of the tiles in terms of emissions compared to concrete, these data are useful. However, as part of a grant, in the past months an expert from TNO has been working on a full life cycle assessment of the Waterweg tiles. TNO has expertise and access to more inclusive data for reference tiles. My recommendation is, if possible, to wait for those results for formal communication with the clients, governments and municipalities. Alternatively, the limitations of the comparison analysis should be very clearly communicated to avoid misunderstandings.

LCA critique: is the LCA framework the most suitable way to measure impact for circular startups?

During this internship, there were a lot of setbacks and difficulties. As previously discussed, Waterweg is a startup that operates in the framework of the CE. The infancy of the company as well as the fact that it uses waste streams as a resource, gave rise to a lot of obstacles that made achieving a satisfactory LCA analysis not an easy task. There is a lot of information and articles on making LCAs for the CE and the difficulties that it entails. However, a short literature research on the topic of LCA for startups revealed that there are very little publications on this topic. The difficulty of the process was clear to me, but I was interested in finding out whether there were some general points that could be summarised for startups working in the circular economy who found themselves in the process of making LCAs. For this purpose, I conducted several interviews with startups and LCA experts to try and summarise their experience. Hopefully, with these insights governmental institutions can have a more critical view on the pressure that demanding LCAs from these companies can bring, and the pitfalls of such an ask.

The startups' perspective

During the process of finding information to make a life cycle assessment for Waterweg, it became clear that finding useful numbers to describe a company's impact is not a straightforward task. This is especially true in the context of startups. Startups by definition are not established companies, they are constantly working on defining their core business models and operations. Furthermore, especially in the context of the circular economy, it is not uncommon to be working with new materials and methods as a core business activity. It is a dynamic, fast paced, constantly changing environment which seemingly does not welcome the rigid, formal process of making LCAs.

To assess the core issues of making LCAs for startups in the circular economy, I conducted interviews with 5 startups currently working in the context of the circular economy. The participants were found via the network that was built by the founders of Waterweg. In the following paragraphs, a short description of each startup interviewed is provided.

The company was originally founded by Marjanne Cuypers in 2010 but only became BlueBlocks in 2020. BlueBlocks uses seaweed to create products. They are at an early stage of development and currently mostly work on pilot projects. SeaWood is one of their products, it is a sustainable wall panel material and can be found in the Exploded View project of TNO, currently being showcased at the Floriade expo 2022. Marjanne has had her LCA informally calculated by students from TU Delft as part of a course in 2021. Furthermore, as part of the TNO project she has had the opportunity of having a TNO expert calculate her LCA which is currently in the works. The interview was conducted over the phone with Marjanne.

Fruitleather was founded in 2016 by Koen Meerkerk and Hugo de Boon. They collect the portion of mangoes from the port of Rotterdam which arrive already inedible. These mangoes are processed and used to create leather like sheets of material. The leather sheets can be processed in the same way as leather, and applied to consumer products such as shoes and bags. Fruitleather has had an intern calculate their LCA for them during 2016/2017. An informal interview was conducted with Hugo in person during a lunch break.

The company was initially founded in 2010 by Jan-Govert van Gilst. After experimenting with bamboo for the first 3 years, Vibers switched to elephant grass as a fiber source. Currently Vibers retains ownership over the whole life cycle from growing the elephant grass to the production of the fibers. The fibers are used as a supplement to produce bioplastics, paper and other materials. Vibers had an LCA made by an official bureau in 2019. The LCA was made for a traffic sign they made for the government, and the LCA had to be made to confirm that its impact was lower than a regular aluminum traffic sign. The interview was conducted in person with Melchior Huijts, who has worked at Vibers since November.

RikMakes is a design company founded by Rik in 2018, of which he is the sole employee. Rik designs interior wall panels made out of agricultural waste. His panels are very similar to wood panels in appearance and intended use, however, they are made in a circular way by using agricultural waste. His work is currently being showcased at the Natural Pavilion in the Floriade expo 2022. Rik has had an LCA made by the Hedgehog company, which he was able to finance via a grant. The interview was conducted over the phone with Rik.

See description in the introduction. Waterweg hired an intern in to make some initial calculations of their LCA and MKI. In 2021, they looked for another intern to continue working on this topic full time. As part of the "Exploded view" project by TNO, Waterweg was able to have their impact calculated by TNO. The interview was conducted over a video call with Eva Aarts, co-founder of Waterweg.

These startups all work in different domains and business models (B2B and B2C), however, they all operate in the circular economy. During the interviews it became clear that they face similar challenges when it comes to measuring impact. There were many interesting insights that came from these talks, which I will summarise in the following sections and extract some points for reflection.

Difficulty with data: collecting and finding

BlueBlocks and Waterweg both directly expressed and recognised the difficulty in finding and collecting data. Working with MVPs on a small scale could mean working with a lot of different machines in a very inefficient way, as is the case for BlueBlocks. This makes the process of collecting data on a startup's own processes very time consuming. On top of that, finding good, up to date databases to match the emissions or impact of a certain process or raw material with its LCA equivalent, can be difficult and/or nearly impossible without paying high access fees. Waterweg, BlueBlocks and RikMakes were able to access grants through which they could have official third parties perform an LCA for them. The collaboration with TNO and the Hedgehog company made it easier to access information, by means of experts who regularly work with LCA software and databases and could perform a good analysis for the startups. Nonetheless, the third parties still required a lot of information from the startups, which can be more or less difficult to gather depending on the startups operations and resources.

Difficulty with data: transparency and validity

Getting a formal LCA done by a third party is a costly investment. Vibers had their LCA done by a third party, and they recognised issues with data in terms of transparency. Their final biocomposite product is made using bioplastics as supplementary material. The manufacturers of these bioplastic materials are often not willing to share their processes, therefore all the data on the impact of their partners is not accessible to them. By signing a non-disclosure agreement, the bureau making the LCA was able to collect this information and deliver final impact measurements. However, the calculations in between were defined as a "black box" of information which was not accessible to Vibers. This lack of transparency makes it difficult to think about making their own LCA. This is a particularly interesting point to consider when talking about startups working in the circular or blue economy, which often rely on partnerships to deliver full products.

A point of concern about data that was raised by all the startups was on validity. Vibers invested a large amount of money to make an LCA for their product, however, this LCA did not remain valid for a long time. Only 4 years later, the bureau which initially performed the LCA updated their databases, making the LCA made a few years prior completely obsolete and invalid. This is a reality that makes it difficult for startups to justify the high investment costs.
Not only do databases get updated, but also the process of the startups themselves is often still not fully established. Any small change in the production process of a given product would completely change the results of the LCA. As a result, any formal LCA certification acquired up until that point would be rendered invalid. This was one of the strongest points raised by all the startups in regards to data.

Difficulty with data: uncertainty

Validity of the results of an LCA is a concern that, outside of obsolete external databases, can also be directly linked to the uncertainty of the internal data the startups have. Part of an LCA, for example, is to assess the end-of-life (EoL) impact of a product. This problem was explicitly recognised by BlueBlocks, Waterweg and Fruitleather. Both of these startups are at an early stage and therefore have not yet had the opportunity to analyse the EoL of their product after implementation. Any assumptions made to describe the EoL could be very far from the truth, making the whole EoL section of an LCA very different based on different EoL scenarios.

The stage of a startup dictates how ready they feel for an LCA

Certainty about a startup's production process comes with maturity of the company. An early stage startup which is still experimenting with raw materials and processes, will not only not have the right data to put together an LCA, but also might not find it useful to do so. This was discussed by BlueBlocks, as Marjanne discussed, it did not feel useful for them to make a full LCA based on their maturity as a company. As she had already had an LCA done previously, she was aware of her impact and already had identified the hotspots which should be given extra attention to. Similarly, Eva from Waterweg indicated that while having an LCA is useful for them, they do not know what their production process is going to be once they scale up, and this is going to have a major impact on the LCA. Therefore, they do not feel ready to make an investment into having one done externally. Fruitleather indicated that they will not be (or invest in) making an LCA as long as their production process is still changing. RikMakes drew similar conclusions, as he mentioned that making a new LCA would be useful once his production process is finalised, which is not the case at the moment. Overall, startups are fast paced, constantly changing environments and an LCA for a startup would only roughly describe their impacts at a very specific point in time.

Lack of resources (time and money).

Making an LCA can be a lengthy process, if one wants to do it accurately. Startups do not have a lot of resources to make an LCA internally. Founders are already working at maximum capacity to develop their product and grow their business. As mentioned by Marjanne from BlueBlocks, it took her an extensive amount of time to gather all the data that she needed to send to TNO for them to calculate her LCA, which caused frustration and needing to work overtime. The founders from Waterweg recognised that it would be impossible for them to calculate their own impact, and decided to hire an intern to do it for them. With these preliminary results they could show that they were working on calculating LCA and MKI, however, these results were very rough and did not give them the credibility needed. Having TNO calculate their impact was very useful for them in terms of credibility and it did not cost them any extra time. This is due to the fact that I was hired as an intern to help with circularity, and I had previously already analysed the whole process and done the data inventory which could be used by TNO to make an LCA. The advantage of this LCA as opposed to what I did, is that it is done in the same exact procedure with which one could get a certification. Furthermore TNO has access to experts, databases and software which provide more information on the LCA impact categories.
All startups explicitly mentioned the costs of having an LCA done by a third party to be too high for their resources to consider it as an option.

Formal markets require LCAs already at an early stage

Waterweg was founded in 2018 during a challenge organised by BlueCity. Already during the challenge, the founders were asked to think about their impact and whether they were planning on calculating it in the form of LCA or MKI. Their primary customers were, and still are, municipalities and waterboards. These are formal institutions that work with rigid processes and have strict requirements for implementing innovative ideas and solutions. It is therefore not surprising that they would require formal numbers such as MKi and impact measurements in the form of LCAs. Not being able to provide these numbers at an early stage hindered the communication between Wateweg and the customers, and gave a strong indication of the level of maturity of the company, still at a very early stage then. Similarly, Fruitleather experienced the same kind of requests from large fashion industry brands. These industry giants were not willing to work together and implement their product without seeing the impact certifications in terms of LCA of Fruitleather's product. Vibers was asked to make a formal LCA only when working with a municipality. During the interview it was brought up that they try to avoid working with formal parties, because of this reason. RikMakes had a similar experience when a large construction company approached him and was interested in his products, but they required LCA and MKI numbers. Formal customers have a lot of requirements (such as LCAs and MKIs values), making it not attractive for a startup to work with these kinds of parties.

How can the process of getting an LCA be made easier for startups?

Summarising the points above it is clear that making an official, certified LCA for a startup is difficult. Data is difficult to gather, databases are hard to find and not always up to date and the production process itself of startups is often still changing, making any calculation previously done obsolete. However, bigger companies and formal clients such as municipalities often require these numbers to employ the innovative products of startups. This begs the question, is progress being hindered by requiring small companies to calculate their impact with such a complicated framework, already at an early stage?

Most of the startups I talked to had already done some analysis into their impact. These are companies operating at the forefront of sustainability, and yet they all understand impact is an incredibly important concept to be fully aware of as a company. Therefore, they all made an effort to get some insights into their processes and try to understand the source of their biggest negative impact, to be aware and eventually correct it. However, none of the startups would be able to make a complete LCA internally. And in any case, as it became clear during the interviews, internal numbers are not enough for certain customers and formal parties to justify working together with the startups.

The startups interviewed had some ideas on how this process could be made better, depending on the stage they are in. At an early stage, LCAs done by student projects in collaboration with universities are a great way to approach a first calculation to understand a company's own impact. The founders are able to get access to full, transparent calculations by inputting very little time and effort. During student projects, teachers are guiding them so there is good quality supervision from experts who know how to perform proper calculations. Furthermore, they can deliver transparent results which the startups can use in the future to adapt the LCA in response to changing processes and products. BlueBlocks took this approach at the beginning of their venture and found it incredibly beneficial. Waterweg tried it as well, however they encountered issues between what was expected of the students by the university and what they needed as a company. The advice is to set up clear goals with the university and the students to avoid running into these problems. The downside of this approach is that it does not give the credibility that a third party LCA would, therefore these kinds of LCA would be useful for internal understanding but not for external communication.

A second approach, as mentioned already, is to get a third party to do an LCA for the startups as parts of grants and subsidies. LCAs and measuring impacts are very important topics, including them into the project activities of subsidies and grants by different institutes should be a given. By doing so, startups get access to experts who can provide them with correct and insightful data and calculate an LCA for them. Having a third party make an LCA for a company gives them more credibility and these numbers can then be used for external communication. The downside is that updating these calculations is not possible, as the startups do not have access to the software and databases used by the experts. This means that the LCA will become outdated the moment something is changed in the process. However, if the startups fully understood the analysis, they can make assumptions on what kind of impact the changes make and they can address it without updating the full LCA.

The last option is to pay a large amount of money to get the LCA done by a certified company. However, this is definitely not the preferred option due to large required investment. Vibers suggested that if third parties require an LCA of the startups, they should finance it and invest in it. This is a good suggestion that could potentially work when working with large companies.

Overall, it would be best if startups and small companies with a low annual turnover would be officially not required to provide full LCAs but rather insights into their emissions. Waterweg for example suggested a market cap of 250,00 euros turnover per year, below which startups should be excused from providing full LCA calculations. This would show willingness to calculate their impact without having the pressure of making a full LCA. Alternatively, governments should set up accessible subsidies aimed at helping sustainable startups get funding specifically for calculating LCAs and acquiring certifications.

The impact assessment experts perspective

Measuring impact is incredibly important in the context of sustainability. This is especially true now that being sustainable is becoming not only something that is good, but also a necessity due to increasingly strict environmental regulations. Unfortunately, a lot of companies, especially in the retail industry, tend to apply greenwashing techniques to convince people that their products are sustainable. But are they really? That is why measuring the impact of a product is vital. As previously mentioned, LCA is one way to do this comprehensively to include all different kinds of impact to the emissions of the life cycle of a product or service. But something that often came up during the course of this internship was the question, is LCA a one fits all solution? Does it truly represent the best way to measure impact for startups in the circular economy?

In order to get insights from experts, I performed 4 interviews with people working in the domain of impact measurement and sustainability. The experts consulted were:

Eva van Eck: Eva works at Noorderwind as an impact measurement expert and project manager, mostly focusing on the CO2 measurement for the company itself as well as finding ways to measure the social impact of the projects that they run. Noorderwind is a company which supports startups and governmental institutions to design and implement sustainable businesses and projects.

Martijn van Bodegraven: Martijn is a sustainability researcher at the RIVM. He has expertise in LCA and impact measurement in the context of sustainability. Martijn went through a similar process as me during his master thesis, as he performed a LCA analysis for a startup.

Furthermore, 2 experts on LCA and impact measurement from a research institute were interviewed. Unfortunately, for privacy reasons I am not allowed to disclose their name and the institute they work for. The research institute is a large non-profit organisation in the Netherlands which, amongst other things, also focuses on sustainability. One of the experts has experience in the construction industry, while the other expert has experience with startups and circular products.

These interviews were conducted at different times and due to the varied nature of expertise, yielded different points of view and reflection. I will summarise the most interesting findings in the following paragraphs.

Uncertainty makes modelling difficult.

It was already brought up by the startups I interviewed that the impact of a startup is difficult to measure due to the uncertainty of their business. This was mentioned as well during the interview with Martijn, who found making assumptions about the startups the hardest thing of making an LCA. He resolved this by implementing scenarios, from the best case scenario to the worst case scenario. This way a range is created that covers and quantifies the uncertainty of the startup at the time of making the analysis. This is a good way to deal with the problem, however, it is of course time consuming.
Both of the LCA experts I interviewed also mentioned uncertainty as an issue but more in the modeling of the end-of-life scenarios, which are represented in module D of the LCA framework. Making assumptions on future scenarios is difficult and you are essentially making a promise that your material will be treated in a certain way, which may not be the case. One of the experts especially made the distinction between performing EoL analysis for scientific research purposes vs for practical applications, such as in sustainable procurement. Making assumptions when researching a material and analysing these assumptions with different EoL models in module D is a great way to assess the sustainability of a material. In practice however, module D is often not modeled correctly.
When it comes to social impact, there is the underlying uncertainty of not knowing exactly what should be measured. As Eva discussed, designers often do not know what kind of impact their interventions are going to have on the population, therefore deciding on how to measure the impact is a difficult task.

Difficulty with data collection and data analysis

Difficulty with data came back as a topic during the interviews with the experts as well. One of the LCA experts mentioned that it used to be difficult to gather the correct data from a manufacturer. However, he mentioned that this has improved over time as more and more parties are interested in making LCAs and have taken the effort to collect proper data on their processes. This is because more and more companies are interested in measuring their impact and especially their ECI. With a lower ECI, manufacturers can justify higher prices and it gives them a unique selling point as opposed to companies who did not make these analyses. Related to which data to use, Martijn mentioned that choosing a product to compare the LCA of a startup to is difficult, as you want to maintain an objective perspective and try not to put your own product at an advantage, but at the same time it is sometimes difficult to find something that is comparable, especially if the product is very innovative.
For social impact, similar struggles exist. While explaining her experience in social impact measuring projects, she mentioned how difficult it is to collect good quality quantitative data that are actually still representative of the population affected by the intervention. She discussed that oftentimes qualitative data in social impact is just as important to collect.

Difficulty with formal institutions and regulations

A very interesting finding that came up during the interview with one of the LCA experts was on regulations of modeling of EoL scenarios. The person discussed that in construction the worst case EoL scenario is the only one that is allowed to be included in module D of an LCA. This means that even if the EoL of a product could be modeled in a circular way, it is not allowed to do so. Effectively, this makes it not attractive for manufacturers to focus on circularity when making an LCA, as this cannot be reflected in the ECI value (which is the value used to secure tenders and projects). This was recognised as a big issue that the institute is now also focusing on trying to solve, as they recognise that this hinders the progress towards circularity. Due to this, the implementation of module D in an LCA, and therefore a cradle to grave (or cradle) assessment is not very popular in Europe. Oftentimes in fact, only the production (module A) is asked. This was mentioned as well by the other LCA expert.
Eva from Noorderwind has experience working with municipalities. She mentioned that, at the start of a project, they always want to measure the impact and think that it is important. However, as we discussed, this is a difficult task. Social impact projects often last very long and can become very complicated to implement. When that happens, usually the first aspect of the project that is dropped or put aside is the impact measurement. This makes continuity in data collection and analysis difficult.

Interpretation and comparison of the analysis

As mentioned by one of the LCA experts, different parties are often asking for different kinds of analysis, depending on their situation. For example some are only interested in the manufacturing, so they will only ask for the production module, while some parties may want information on the circularity. The data that comes out of an LCA analysis therefore also varies. For example, ECI values are often used in construction and they include information on all emissions. This makes the value more inclusive, but also more vague as more categories are included, which increases the uncertainty for interpretation. On the other hand, other parties may only be interested in CO2 emissions or nitrogen, which makes the data less inclusive but more precise as it only includes a few values. Interpretation of the data therefore can be difficult to do amongst different parties. While discussing his experience on making an LCA for a startup, Martijn shared that interpreting the results of an LCA can be difficult for a layman as it can be a very complex analysis. There are two optional steps in the LCA which could help in putting the analysis in an understandable context, namely weighing and normalisation. With these steps, the impact assessed in the LCA can be put in the context of the real world, which could help startups better understand their impact and actually be equipped to do something about it.
Talking about social impact, as previously mentioned Eva talked about how the effects of a certain intervention are not known beforehand, therefore there is no predicted outcome. This means that making a reference before and after an intervention is impossible, meaning that a time comparison of the effects of an intervention before and after implementation cannot be done.

Communication between professionals and clients

Communicating sustainability is difficult. Especially when the analysis is done in the form of an LCA, which is a complicated framework. The LCA experts both recognised this as a big struggle. They are used to a certain jargon that they use to describe particular sections of the LCA framework. However, oftentime the people they make LCAs for do not use these terms and therefore cannot follow the conversations. The key to good communication is to reduce the complex analysis into understandable key messages and results. One of the suggestions for example was to use percentages rather than the actual value of each impact category. This was also recognised by Martijn during his time working with startups founders, he found it was better to keep the communication at a higher level and to the point, and try to avoid getting into too many details.
A deeper issue lies in trying to communicate the relationship between circularity and environmental impact. This is due to the fact that they describe different things, materials and emissions respectively. As a society we often try to communicate in monetary terms as that is easy to understand. Emissions are easy to relate to costs, however, materials in terms of circularity it is not. This is due to the fact that secondary materials that come out of the EoL of a product always hold a lower monetary value than the initial product. This is a problem because in these terms, the true value of circularity cannot be captured nor properly described.

Lack of positive impact categories

Both the LCA experts recognised that the LCA framework is set up to describe the emissions, which are by definition negative. There is no way to include positive impact within an LCA, the only way is to include something that has a positive effect on the emissions, therefore reducing the emissions. But inherent positive impacts are not included. The institute they work for also recognised this as a problem and is working on including social impact to counter this.
In this regard, Noorderwind and the municipalities are already ahead as they have been trying to implement this and find a way to properly measure the positive impacts. Eva mentioned that there are currently two ways to look at this. Firstly, one can look at the inputs within an intervention and compare the results with another intervention later in time. Another way to do this is to try to assess what the impact of a certain intervention is in the bigger picture. This is harder to do, because of the issues that were already discussed in previous sections.

Summary of expert interviews

Talking to these diverse experts was very interesting. Despite having different domains of expertise, a lot of the points that were raised could be extrapolated and generalised to certain issues relating to measuring impact. It became clear that there are many struggles still when it comes to analysing emissions in specific industries or contexts. Furthermore, social impact is an important aspect to consider that is currently not included in more formal impact assessments methods such as LCA. However, it is such an important topic that big research institutes are already working on including it.

Discussion on the interviews

The interviews were a great way to get insights into the opinions of startups and experts on their experience with LCAs. Unsurprisingly, many of the startups had a similar experience and similar approaches to the obstacles of making LCAs. Many of the points raised by the startups correspond to similar conclusions drawn in literature, such as the negative effects in measuring impact due to the maturity of the company, the lack of resources and the uncertainty of the manufacturing process and business models [17]. Nonetheless, It was shocking to find out that startups may decide to avoid certain markets and clients, and possibly slow growth as a result, due to having to provide LCA analyses. It is ironic that something which was developed to improve the environmental impact of companies, is now hindering the development of startups whose core mission is to be sustainable and good for the environment. A solution needs to be found to help startups successfully overcome this obstacle. In literature, one approach was studied in the form of an LCA clinic. In this study, four startups and small-medium enterprises participated in short sessions to put together an LCA of their product or business. In the cumulative time of approximately one day for the companies and one day for the LCA experts, they were able to get an LCA of their products. This activity was positively received and the companies were able to implement tangible changes based on the results of the analysis. [18] LCA clinics could be a low cost solution to provide insights to startups to counter their lack of resources, both in terms of time and finances. However, this would still constitute an investment. Ultimately, it might be beneficial for governmental institutions to make this investment for early stage startups that operate in the domain of sustainability and require these numbers for their operations.

The impact measurement experts had some similar conclusions as the startups. They also struggle with data, uncertainty and working with formal and governmental institutions. What was really evident during these interviews, is how many shortcomings still exist for making LCAs in the context of CE. Some of the issues were already identified in literature, and were confirmed by talking to these experts. The rules on how to make LCAs can be complicated when working with waste streams. The allocation of environmental burdens and benefits is not sufficiently defined and proper guidelines on how to do this are still lacking [19]. Furthermore, as it was already discussed extensively, there is a fundamental lack of inclusion of positive indicators for the good aspects of products that come with CE companies and startups. The good news is that the ISO is currently developing a new framework to assess the impact of products that are operating within the CE. [20] This standard is being developed by the technical committee ISO/TC 323, the proposal has been drafted and it currently on the last preparatory phase before being reviewed and eventually published [21]. Until then, experts will still need to rely on their own best judgement on how to properly deal with circularity within the LCA framework.

Conclusion

The research conducted during this internship was two faceted. On the one hand, the initial task was straight forward: analyse the LCA of Waterweg's product and deliver the results of the analysis in a useful way. On the other hand, the process turned out to be so complicated that it became also very interesting to dive deeper into the topic with a more critical view. After a lot of conversations and interviews, the critiques were formalised into general topics that startups and experts recognise as challenges when making LCAs for startups in the CE. This research was a good step into understanding the underlying issues. For the future however, the involvement of governmental and formal institutions is essential to try to tackle some of these issues. As it is right now, the LCA framework is severely hindering development for startups working in sustainability and accessible, long-term solutions are needed to help startups do their best work without unnecessary extra struggles.

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