From demolition waste to circular construction through partnerships – Reusing old bricks in North Jutland

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Preface

The present report has been conducted by a student enrolled in the Cities and Sustainability Master's Program at Aalborg University in Aalborg, Denmark. The author has a study background on construction obtained back in her country, Italy. The report is illustrated in relation to the circular economy system and focuses on the reuse of bricks in Denmark and follows the PBL (Problem Based Learning) approach that is promoted by the university. In this regard, it uses as a study case North Jutland after providing a national analysis of three main concepts i.e. construction waste and management, waste hierarchy and circular economy as well as their connection. Additionally, is used an already redacted LCA to sustain the theories used.

Acknowledgments

I would like to thank my supervisors Henrik Riisgaard for his support and guidance throughout the process of conducting this report. I believe that without his help the outcome of the present report would have not been appropriate. Additionally, I would like to thank my interviewees: Svend Roed Larse, Claus Juul Nielsen and Kurt Brandi for making the time to talk with me and help me with gathering the relevant information for to reach the outcome of the present report. I would love to dedicate the effort dedicated to write this thesis to my Mom, that I am sure, would be proud of me by seeing me reaching this final stage.

Reading guidelines

The present report is structured based on sections and sub-sections. A full list of each of them can be found below as the Table of Contents. A table with the different acronyms used in the report is given at the beginning of the paper, while at end is provided a list of the figures used through the report. The referencing style used is Chicago, as suggested in the Semester Description of the master's program. Additionally, a full Reference List is provided at the end of the report which is followed by an annex that outlinet the questions asked during the interviews.

Aalborg University – School of Architecture, Design and Planning Urban, Energy and Environmental Planning – Cities and Sustainability

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Project title
From demolition waste to circular construction through partnerships - Reusing old bricks in North Jutland

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Abstract

The waste stream generated by the construction industry become in 2016 the biggest stream in Europe which called the same industry to rethink of their system. In Denmark, the bricks are among the most used construction material since 95% of buildings are composed by bricks. It is calculated that around 47.3 million bricks every year could be reprocessed to be reused, but nowadays only around 3 million of bricks are reintroduced in the market as they are. In facts, the rest of them is downcycled, a practice that is considered not to be the most sustainable solution available in the market. The report starts off with studying the Danish context in regards of extraction and consumption of raw material and the generation of waste produced by the construction industry. It seeks to understand what are the different problems that lead the stakeholders to downcycle and use new bricks instead of preparing old bricks to be reused which would reduce the extraction of primary raw material along with the impacts on the environment. As solution is suggested to use an existing technology to improve the collaboration among the stakeholders involved during the different life cycle phases of the bricks. The report focuses on applying the solution on Nord Jutland region and aims to improve the circularity of the current system of the bricks' market to achieve a better sustainable system.

The image used in the cover represent the Frederiksbjerg school built in 2016 using 400'000 bricks taken from demolished construction and designed by Henning Larsen Architects in collaboration with GPP Arkitekter, Møller & Grønborg and Kari Moseng and built by Hoffmann with Niras as consulting engineer.

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Summary

Table 1 Acronyms Used

Name	Acronym
Affaldsselskabet Vendsyssel Vest I/S	AVV
Business Region North Denmark	BRN
Circular Economy	CE
Construction and Demolition Waste	C&DW
Department of Environmental Engineering	EPA
Europe Union	EU
Greenhouse Gas	GHG
Life Cycle Assessment	LCA
Life Cycle Impact Assessment	LCIA
Life Cycle Inventory	LCI
Wate Framework Directive	WDF

1. Introduction

In 2016 about 374 million tonnes of construction and demolition waste (C&DW) was generated in the Europe Union (EU) becoming the largest waste stream in Europe and so defined as a priority in the Circular Economy Action Plan (EC 2015) in order to close the loop and reduce the unsustainable use of raw material in the European context. The revised Waste Framework Directive (WFD 2008/98/EC, amended 2018/851) sets the mandatory target that 70% of C&DW must be recovered by 2020. The goal is to create a system in which the waste is considered and treated as resource to be reintroduced in the economy system (2020/1 2019).

Ninety-five percent of buildings in the country are built using bricks (Danske Boligarkitekter s.d.) and so it is considered to be among the most used material in the construction industry which also generate a high production of waste that is currently downcycled, a practice that is not considered the most sustainable solution available for the waste management (Miljøstyrelsen 2017). The report studies the possibility to improve the use of old bricks in Denmark proposing a concrete solution to be applied in North Jutland region.

Denmark is the southernmost country in Scandinavia with a total of about 5.5 million inhabitants (Ministry of Foreingn Affairs of Denmark s.d.). It's a developed and industrial country divided in 5 regions, the Capital Region in which is located the country's capital, Copenhagen, The Zealand region, Southern Denmark, Central Jutland and Northern Jutland (Danish Regions 2012).

Figure 1 Denmark (Region Nortdjylland s.d.)

The production of bricks requires the use of natural resources such as clay (the main raw material used to obtain bricks) and sand (which is used during the manufactory process for different purposes, such as changing the colour of the final product or the consistence of the clay). In 2017, in Denmark 31.9 million m3 of raw material was extracted, which is 2.4 million m3 more than the quantity extracted in 2016. Figure 2 shows how the consumption of raw material has been increasing over time and how it will keep raising in the future. The construction industry is considered to be among the most responsible of this increment since it constantly makes use of raw material to realize its products, for example bricks and cement, which could be avoided if the waste generated by this industry would be managed properly (Region NordJylland 2019).

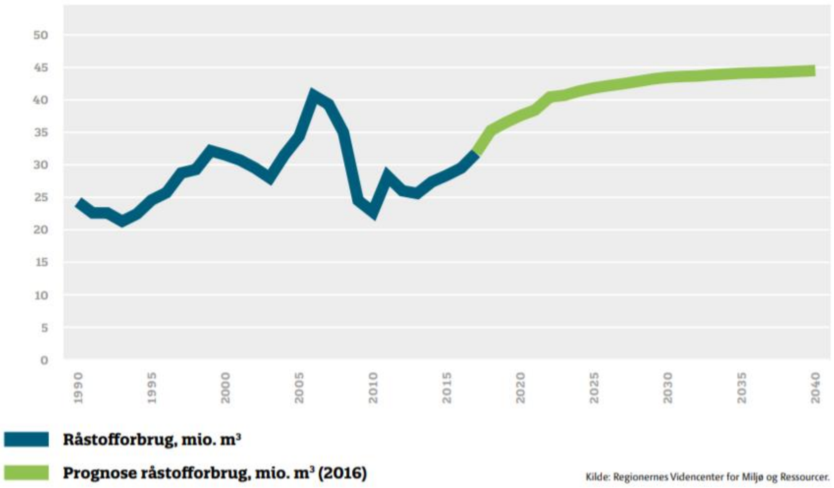

Figure 2 Projections of raw material consumption at national level, DKK million. m 3 (Region NordJylland 2019)

Figure 3 shows the different grades of raw material extracted in Denmark in 2017. Central Jutland result to be the most affected by this practice since the land in this area is richer in terms of resource and so can offer more types of material. There is often a mismatch between the places where the raw materials are extracted and where they are used so they are often transported across the country (Region NordJylland 2019).

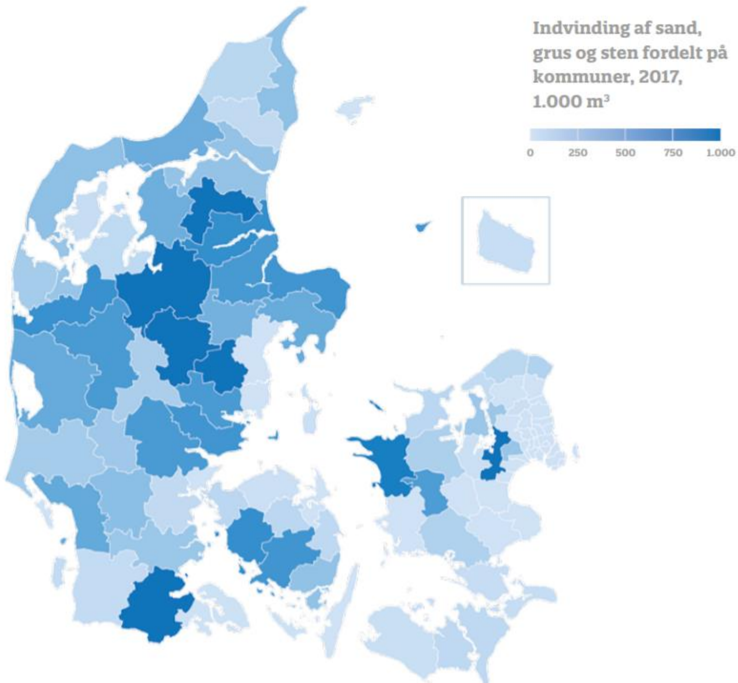

Figure 3 Extraction of Raw Material in Denmark (Region NordJylland 2019)

According to the Sustainable Europe Research Institute, the Danish country resource consumption raised from 21.8 tonnes to 25.3 tonnes between 1980-2008. Currently, over 90% of the construction waste is recycled in Denmark, but it replaces only 7% of the raw material consumption since most of the material is downcycled or incinerated. It is important to make extra efforts to reduce the consumption of natural resources and to promote the use of secondary raw materials which would help to unburden the impacts that the extraction and use of primary raw material has on the environment (Region NordJylland 2019).

As mentioned, Clay is the main raw material used to produce the bricks and is one of the most abundant natural mineral material in the world. 639 000 m3 of clay was extracted from the Danish land in 2018, of which 139 000 m3 came from North Jutland. If compared to the previous year there was an increment of extraction of about 147 000 m3 across the country, and of 56 000m3 in North Jutland (Statistics Dk s.d.).

The extraction and the processing of raw material arouses irreversible ecologic changes and so have an impact on the environment since this action involves interventions over large scales and affect the water balance. It is responsible of air pollution since the extraction happens using machines that are fed by fuels and constantly transported across the country. It provokes soil pollution because the process of extraction degrades the land preventing the possibility to use it in the future for other purposes, such as the agriculture one (Umwelt Bundesamnt 2019). The continuous extraction of natural resources goes against the concept of sustainable development which seeks a growth of the economy dimension without negatively impacting the environment and the social dimensions, so to "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Academia Impact s.d.). This same definition is indeed based on the fact that resources are limited and should be used carefully and wisely with a view of long-term concerns (Sustainability s.d.) .

In 1973, Denmark became the first country in the world to have an environmental protection law, which focused on dealing with the waste management. Incineration and composting were the first solutions proposed, which aimed to save lands to be used as landfill and at the same time contributed to the production of heat and electricity during the 80's. Between 80's and 90's the country became one of the first countries in the world to achieve a high recycling rate minimizing the use of landfill by developing a regulatory framework to manage the waste (Denmark : we know waste s.d.)

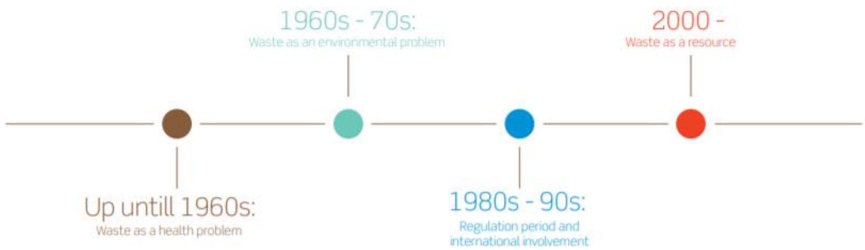

Figure 4 Description of the history of Danish waste management (Denmark : we know waste s.d.)

In 2010 a new strategy of waste prevention was launched with the purpose to reduce the use of landfill as final solution. It sought to use the waste as a resource and not as something to get rid of. To reach this vision, the government enhanced the reuse, the recycle and the conversion into energy of the waste. In the Danish context, waste is a responsibility that belong to public and private actors within the municipality. With this system, the different actors can collaborate buying and selling residual fractions to each other, in fact what it can be not useful in one industry it can be it for another one (Denmark : we know waste s.d.). "Businesses are responsible for ensuring correct waste management for their wastes" (Viborg Municipality 2017).

Construction and demolition waste (C&DW) is anything that comes from construction works, including materials that comes from clean-up, buildings, excavation, renovation, road works and demolition (2020/1 2019). Once the life cycle of the construction is done, the material used to realize it must be sourced-separated and a selective demolition should happen if the material wants to be reintroduced in the economy system. Construction and demolition, in accordance with Danish Waste Legislation, are sorted out in Natural stones (granite and flint), Non-glazed tiles (bricks and roofing tiles), Mixtures of materials of natural stones (non-glazed tiles and concrete), Concrete, Gypsum, Ferrous and non-ferrous metals, Rockwool, Asphalt, Soil, Mixtures of concrete and asphalt (Viborg Municipality 2017). Further, the waste is analysed and can be classified "into clean, contaminated or hazardous waste" (Viborg Municipality 2017).

The construction sector accounts for more than 1/3 of the waste produced in Denmark with a waste generation in 2017 of approx. of 4.5 million tonnes (Miljøstyrelsen 2017). The sorting of C&DW in Denmark is made by using the European Waste Catalogue (EWC) code or generally known as the waste classification code, a legal requirement in EU countries when waste produced by businesses is sorted out to be recovered and disposed. This catalogue is divided in chapters and sub-chapter and provides a standard description of the different wastes that can be generated and how they should be treated. It is believed that this is the most efficient list to refer to when C&DW is produced, since it is composed by different fraction of mixed materials and parts of buildings (Novus Environmental 2017).

The recycling of construction waste has fallen from 88% in 2013 to 85% in 2017. It is important to specify that the data referring to recycling here, includes the processes of recovery and downcycle, even if they are different. At the same time there was an increment in the use of landfill, as for the use of incineration which grew 3% from 2015 to 2017 (Miljøstyrelsen 2017).

Concrete as well as asphalt and coal-containing waste constitute by far the largest quantities of waste with a share of 48% over the total, while mixed building, fractions of concrete, brick and ceramic account for 20% which have remained stable since 2015 reaching the amount of 900,000 tonnes. An increment of bricks and ceramics waste between 2016 and 2017 has been registered which is thought to be connected to the fact that that companies are focusing more on sorting individual fractions and adopted the use of EWC code to treat the waste generated by these materials. In facts, in the past bricks would be crushed along with other materials without being identified, but now because of the EWC code, the material has to be separated from others and catalogued separately, so the quantity of bricks wasted might be the same as the past but the adoption of the new system helped to be more specific and therefore the quantity of waste coming from the bricks raised (Miljøstyrelsen 2017).

Hereby the report focuses on the use of bricks, since is among the most used material in the construction industry and it still has a low rate of reuse. In fact 47.3 million of bricks each year could be reprocessed to save around 22 500 of CO2 emissions, but currently only about 3 million of them are reintroduced in the system as they are and the rest is being downcycled (Miljøstyrelsen 2019). The preparation for the reuse of bricks is considered to be a more sustainable solution than the downcycle or the production of bricks itself, since allows to reduce the consumption of raw material and cuts energy consumption by 98% if comparted to the production of new bricks. Moreover, for the construction of an average home, which requires the use of 16 000 bricks, 8 tonnes of CO2 emissions would be saved if old bricks would be used instead of new one (Gamle Mursten North s.d.). Additionally, the improvement of the reuse of bricks can contribute to add social values since it is estimated that in Denmark this approach could create 400 extra jobs (European Commission 2020).

This reporter believes that a change in the current system is needed and focuses on finding a solution to make a better use of old bricks with the purpose to improve the current system to make it more sustainable. The reporter believes that this shift would bring benefits over different aspects across the three dimensions (environment, social and the economy), less damage would be brought on the environment as on humans' health and more job positions could be created.

The report will first outline the theorical framework, followed by the research design and the research findings. An explanation regarding the characteristics needed by the bricks to be used in the construction field is given and it is followed by the description of the three processes of production, downcycle and reuse of bricks. An LCA is used as a technical proof to show how the reuse of bricks is more sustainable than the other two practices. Different problems that stakeholders face during the life cycle of bricks are highlighted and a is given a solution that suggests the use of a new technology with the improvement of collaboration and communication among the stakeholders that work in the bricks market.

2. Framework

This section explains the theoretical framework used in the report to analyse the data, the current system, processes and to provide a solution to the research questions. The theory used are in order: Sustainable

Development Goals, Waste Hierarchy, Circular Economy, and the explanation of the tool Life Cycle Assessment (LCA). Each concept is explained and clarified with reference to the context of the paper and directly connected.

2.1. The Sustainable approach

2.1.1. Sustainable Development

The General Assembly of the United Nation, in the early 1980's called for new actions to protect the environment and as result a global agenda for change was created. In 1987 the Brundtland report was released and clarified the concept of sustainability and it was put at the centre of the world development. As mentioned in the introduction, sustainability is considered to be a complex concept defined as the practice that "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Academia Impact s.d.). This definition it is based on the fact that resources are limited and should be used carefully and wisely with a view of long-term concerns and repercussion thinking of how they are used (Sustainability s.d.).

2.1.2. Sustainable Development Goals

The ecological footprint index, thirty years later the Brundtland report, (paired up with the world development) shows that countries like Denmark exceeded the sustainable world biological and ecological capacity (Andreas Q.Sechera 2017). Looking at data of emissions, world projection and uses of global material, it has been noted that is essential to reduce the greenhouse gas emissions along with the use of natural resources and that the technology needs to be improved to be environmentally friendly. The building industry, every year, uses around 40% of raw material extracted and it also among the industries with a high use of energy (Andreas Q.Sechera 2017).

In 2015 the United Nations gathered to create a new plan to reinvent the world system that would be more sustainable and would take in consideration the impact that human's actions have on the environment. The governments have agreed all together on the topics and goals considered to be the most pressing issues and committed to finally find a solution for them, creating "The 2030 Agenda". It is composed of 17 goals with a total of 169 targets (Nations United s.d.)

Figure 5 Sustainable Development Goals (Nations United s.d.)

Specifically, the challenge for the construction sector is to identify and integrate a holistically sustainable approaches to achieve business goals and economic health. It influences directly and indirectly the environment under different aspects through the extraction and the use of limited resources and the generation of waste. The writer selected and analysed the following SDGs and targets since they are the key to reach the purpose of this report and a connection between them has been highlighted and further visualised in figure 9. The SDG 12 is considered in this report the central goal to achieve and was created to ensure sustainable consumption and to guarantee sustainable production patterns and it broadly deals with material consumption and material footprint per capita. It aims to ensure that unessential extraction and the degradation of natural resources will not happen and uses new policies to improve the resource efficiency, reduction of waste mainstream and guarantee sustainability practices across the three dimensions (Nations United s.d.). This report focuses on showing how the reuse of bricks is more sustainable that their downcycle or their production, therefore it is seeking to create a system that would wisely make use of natural resources and pursues to improve their sustainable management (target 12.2), which leads to improve to avoid chemicals and construction wastes to reduce air, water and soil pollution to minimize their negative effects on humans' health and on the environment (12.4) (Nations United s.d.).

The target 12.4 can directly work with the 3.9 which aims to "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination" (Nations United s.d.). While, keeping in mind that the report is working with the bricks market and therefore the construction industry and that water is used in different moments during the construction of infrastructures that use bricks as material, it can be created a connection with the target 6.3 which works with improving the "quality of water by reducing pollution eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" (Nations United s.d.). It also exists a connection between the target 12.4 and 6.4 which aims to "substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity" (Nations United s.d.). Going back to the SDG 12, another target was selected, the 12.5, which wants to "reduce waste generation through prevention, reduction, recycling and reuse" (Nations United s.d.) and therefore a variation in consumption and production is sought along with the decouple of the economic grown from the environmental degradation (8.4). Construction companies, as every company, should adopt sustainable practices and provide information to their employee regarding the sustainable solutions available (12.6), and so must upgrade their infrastructure to be sustainable and consequently to improve resource-use efficiency (9.4) (Nations United s.d.). Finally is essential to "Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts" (Nations United s.d.) (12 C). Doing so is possible to protect, restore and promote sustainable use and access to terrestrial ecosystems and limit biodiversity loss (15.6). The last target can be connected to the target 7.1 that wants to ensure "access to affordable, reliable, sustainable and modern energy" (Nations United s.d.) for everybody, and 7.3 which aims to "double the global rate of improvement in energy efficiency" (Nations United s.d.) in fact the construction industry is among the industries that make high use of energy which is among the sectors that most influence the GHG emissions, since is obtained through the burning of fossil fuels. Doing so is possible to "reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management" (Nations United s.d.) (11.6).

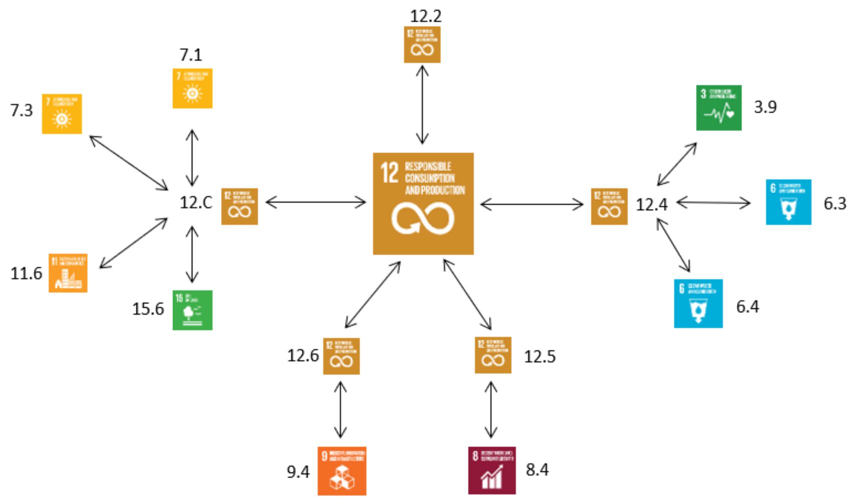

Figure 6 Connection od SDG 12 with the different SDGs

2.2. Waste Hierarchy

2.2.1.General Definition

The SDG 12 as for the other SDGs, have an ally in the Waste Hierarchy, a policy instrument that aims to ensure to make aware everybody of the different existing options that help to prevent waste and to improve its management in order to protect the environment and improve the management of natural resources to increase the material use efficiency. In the construction sector, the waste is managed by the revised Waste Framework Directive (WFD 2008/98/EC, amended 2018/851), which sets specific targets for construction and demolition waste (C&DW), introducing the concept of the end-of-waste and using a hierarchy to define the best sustainable approaches to use to manage the waste (2020/1 2019).

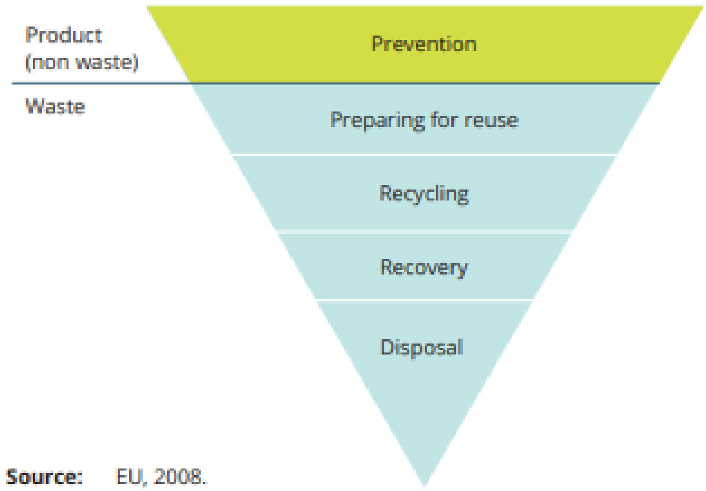

Figure 7 Waste Hierarchy (2020/1 2019)

"Member States shall take measures to promote selective demolition in order to enable removal and safe handling of hazardous substances and facilitate reuse and high-quality recycling by selective removal of materials, and to ensure the establishment of sorting systems for C&DW at least for wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic and plaster" (2020/1 2019).

As showed by figure 7, the waste management hierarchy is usually presented as a pyramid and it is divided in two main levels: the first one represents the willing of minimizing the production of waste since the beginning of the product life, while the second level shows the option available in the case the prevention was not possible. The top of the pyramid which is pointing at the bottom is the least preferred method sought and identifies the disposal of waste in landfill. The stream on the top, which is the base of the pyramid, is the best approach in terms of sustainability and identify the action of prevention (2020/1 2019).

Prevention is identified by the WFD as "measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of harmful substances in materials and products" (Kim Talus 2016). It seeks to avoid the generation of waste and to reuse the product as it is without going through any treatment. This is possible only if the right measurements are taken since the product is born and through the whole product's life. Doing so would help the purpose of reducing the use of natural resources. When the waste needs treatments to be reused, is not considerate anymore on the prevention level (Kim Talus 2016)

The second most sustainable action for the waste hierarchy policy is the preparation for the reuse followed by the recycle action. Both are considered waste management measures in which the waste is being reused in different contexts and for different purposes avoiding the use natural resources (Kim Talus 2016). Specifically, the practice of preparing for re-use is identified by the WDF as the "checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing" (Kim Talus 2016). The action of Recycling is defined as "any recovery operation where waste is reprocessed into products, materials or substances whether for the original or other purposes" (Kim Talus 2016). For the level of recovery there are different school of thought, but the report wants to use the definition provided by the WDF which locate on this level material and waste that is being transformed into energy by incinerator. The reporter located on the same level the downcycle approach, which is not defined by the WDF, but it was decided by the Commission Decision 2011/753/EU that this practice is "a recovery operation where suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials" (2020/1 2019). The practice considered the less sustainable is the disposal which uses land as site to dispose the waste or when incinerators are used but energy is not produced (2020/1 2019).

The aim of this policy is to treat the waste as a resource to optimize the use of the limited natural resources and therefore to avoid the generation of waste that would affect the lives of the future generations (UNEP 2013). Additionally, waste prevention, reuse and recycle delay the needs of primary raw material and help to low the emission of GHGs emissions (2020/1 2019) which are gases that can trap sun's ray and trap them into the atmosphere up to thousands years and are known to be among the most responsible for the global warming and climate change. The most known GHGs known are Carbone Dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), and Fluorinated gases. They can be trapped in the atmosphere up to thousands of years and can mix up (Environmental Protection Agency 2018) and metric measure used to compare the different emissions is the CO_2 equivalent, which convert the other gases on CO_2 by associating their global-warming potential (GWP) (European Union s.d.). The GWP describes "the relative potency, molecule for molecule, of a greenhouse gas, taking account of how long it remains active in the atmosphere" (European Union s.d.).
Moreover, the improvement of waste management also helps to create new job opportunities and the health of people since less GHGs are emitted during the different phases (2020/1 2019).

2.2.2. Waste Hierarchy and C&DW

The construction industry to create its final product, makes use of natural resources which are limited. Once the final product reached its purpose is demolished and therefore the resources used in the past to realize it, become waste. This is the so-called linear system, which makes use of the natural resources only one time before becoming waste. As mentioned in the introduction, the construction industry produces the so-called C&DW, anything that is produced during construction, renovation, civil, roadwork, and site clearance and demolition (2020/1 2019). As for any sector, the construction industry is influenced by the law imposed by the governments. If a law that deals with natural resource, waste generation and its management is not existing or poorly applied, it will be difficult to find a stakeholder that would willingly show a commitment to reach a sustainable approach. The C&DW is mostly downcycled and as mentioned above, the practice is classified as recovery and it is located on the second last step on the waste hierarchy pyramid and therefore it is not the best solution in terms of sustainability (2020/1 2019).

It is the most used method since is the quickest and cheapest process present in this industry to get rid of the waste. The practice of reuse is more expensive and time consuming since this practice requires a selective demolition which calls for skilled labours that can be difficult to find and they are paid more than workers with regular knowledge. Additionally, specific machines are needed to sort out the waste which is often done on the demolition site which can cause space problems. Once the material is sorted, is sent to the factory to be treated and reintroduced in the market, but it can happen that some of the materials are too damaged to be reprocessed and this causes a loss of income to the stakeholder that sent the material to be reprocessed since he paid the shipment and was counting on recovering money out of the material sent. One more reason that drivers stakeholder to downcycle the waste, is the fact that the construction industry is a highly competitive sector and therefore the stakeholders don't want to lose time on managing waste since they have to start with other projects as soon as they get the call (Chinda 2013).

Summing up, nowadays the construction industry mostly adopts a linear system, which makes use of natural resources that are limited in nature and eventually become waste once the purpose of the infrastructure is achieved. The waste hierarchy policy was born to help stakeholders to understand how to prevent the creation of waste and how to manage it so that the economy and the social dimensions can still grow without damaging the environment.

2.3. Circular Economy and Construction

2.3.1. General Definition

Circular Economy (CE) is a specific system that works along with the waste Hierarchy tool policy to have better results in terms of sustainability and waste management to avoid the use of natural resources and considers the waste a resource (Circular 2015).

The current system of production and consumption mostly adopted nowadays, is linear which means that the life cycle of a product/material starts with the acquisition of limited resources provided by the Earth and manufactured, packed, transported and used and afterwards disposed. This system makes use of large quantity of cheap, easily available energy, materials and water which consequentially has an impact on the environment, social and economy dimensions, and additionally on the future generations as is taking from the Earth something that could be easily avoided since other solutions are available (Circular 2015).

Figure 8 Linear System (Idaho Forest Products Commission s.d.)

The resources that once were available in big quantity and easily accessible, now are reducing in quantity and becoming more expensive. This situation can be improved by shifting from a linear to a circular economy (CE) system (Eline Leisinga 2017). It focuses on analysing and optimizing the industrial systems, developing an economic model of production and consumption that are working with closed material loop. As mentioned in the introduction, in Denmark in 2017,only 7% of raw material used in the construction industry, it is reintroduced in the economy system (Region NordJylland 2019).

Change the current production and consumption patterns is essential since, as mentioned, the current system is having a considerable impact on the planet and its environmental capacity as on the social and economic dimensions. The goal is to close the loops slowing down the consumption of raw material by using waste as a resource and add value to the products as to the material that is used to obtain it (Eline Leisinga 2017).

Julian Kirchherr with the help of two colleagues, wrote a paper in which he was able to find 114 different definitions of CE and gather them in 17 dimensions. With this paper Kirchherr highlighted how CE is frequently described as a combination of reduce, reuse, and recycle actions, and how is used along the concept of sustainable development (Julian Kirchherr 2017). Here is clear how this tool follows the Waste Hierarchy policy to achieve a sustainable system.

The reporter decided to use the definition of CE provided by Ellen MacArthur Foundation (EMF) which is believed to be one of the most accurate by Kirchherr himself since meticulously describes the different

options that the system has on the regards of waste management and recognize the importance of working with it over different scale, from the smallest business to the biggest one (Ellen MacArthur Fondation s.d.). “A circular economy favours activities that preserve value in the form of energy, labour, and materials. This means designing for durability, reuse, remanufacturing, and recycling to keep products, components, and materials circulating in the economy. Circular systems make effective use of bio-based materials by encouraging many different uses for them as they cycle between the economy and natural systems” (Ellen MacArthur Fondation s.d.). It avoids the use of non-renewable resources and aims to preserve and enhance the renewable ones to support the regeneration of the ecosystem (Ellen MacArthur Fondation s.d.).
A diagram called “Butterfly Diagram” was created in order to visualize the meticulous definition given to CE.

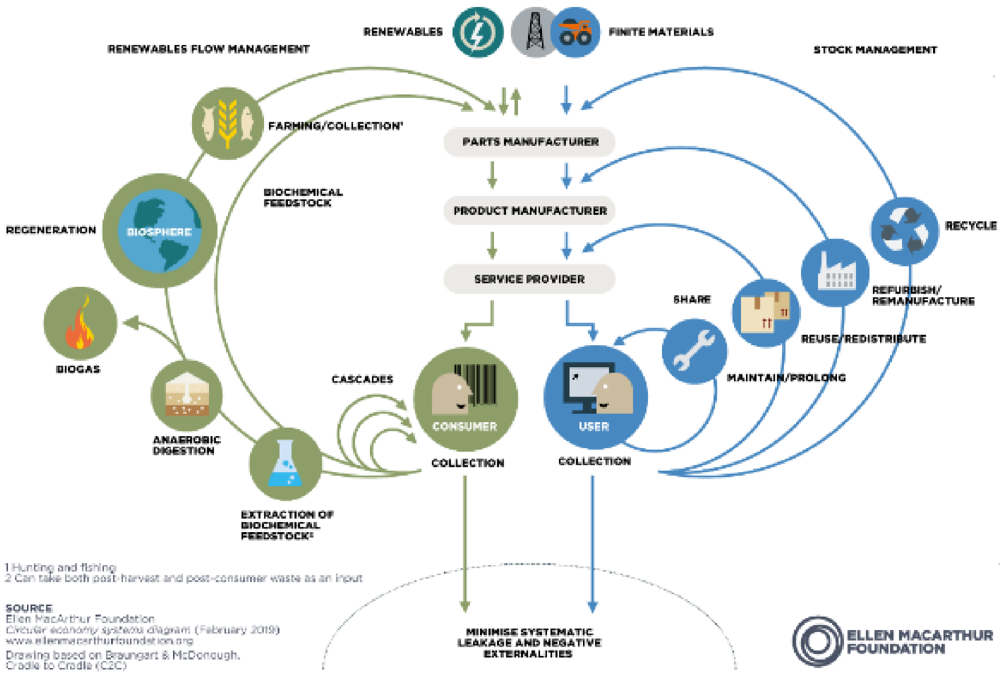

Figure 9 The Butterfly Diagram (Ellen MacArthur Foundation s.d.)

The diagram wants to decouple the economy growth from the development by creating two different cycles. The blue circles refer to non-biodegradable material. Here products’ components and materials are kept in circulation in the economy as long as possible. Instead, the green circle, identifies the biological material and it has the purpose of restoring nutrients in the biosphere while rebuilding natural capital. The most effective strategy is to share, maintain and reuse the products and their components. With this approach, the value of the product is maintained, and a longer life is guaranteed. It is possible that a stakeholder does not need a specific product anymore, but it can be probably useful for someone else even in a different market, and therefore, the reuse of the same product is possible. Instead when the product cannot be used anymore as it is, most of its values can still be retained by refurbishing it or remanufacturing it. If this is not possible, the product can be recycled. Here, the value of the product itself is lost, but the value of the materials that compose the product is preserved (Giraldo 2017). This system follows the waste hierarchy policy which, as explained, wants to avoid the generation of waste and when is not possible, it considerate the waste a resources that can be reused as it is or on other forms (after treatment)and in different contexts (2020/1 2019).

Biodegradable material such as food or wood-based products, can be put in the biological cycle, these materials can be renewed by the nature, but further value can be created by cascading them for additional applications in different value streams. In a biorefinery, conversion process can produce high value of chemicals and fuels products. Organic material can be composted or anaerobically digested to extract valuable nutrients, such as potassium and phosphorus. By leveraging these recovery strategies, it is possible to minimise systematic leakage and negative externalities (Giraldo 2017).

2.3.2.Network Dynamics

The key to have a CE system is the creation of relationships among stakeholders across businesses with the purpose of creating a social network. This allows to have the three dimensions (environment, social and economy) to work together which is the base to have a sustainable system. In the construction industry three principle elements must been considerate and combined to exchange resources: actors, resources, and activities. Therefore, to have a CE system working fully is important to know the actors involved and their activities during the product life, define the relationship among the actors looking at the strategic element of organizational support, to get to know the collaboration element of cross-functional activities and the cultural element of trust development (Eline Leisinga 2017).

For the transition into CE, a redesign of the business model is essential. The new model should deliver environmental, social values along with the growth of economy. In the construction industry, this model includes the change of ownership of material, products and how they deal with them (Eline Leisinga 2017). Primary raw material will always play an important role in the economy, but with the help of the CE system it is possible to reintroduce the material in the economy cycle as many time as possible, so not to extract more primary material if not eventually needed (European Union 2019). Said so, the material used in the construction must be renewable and delivered in a functional way to make it sustainable. The final product must have a purpose for the society and a develop scale-up solution. This Is possible only if rules in the administration of the material are set (Eline Leisinga 2017).

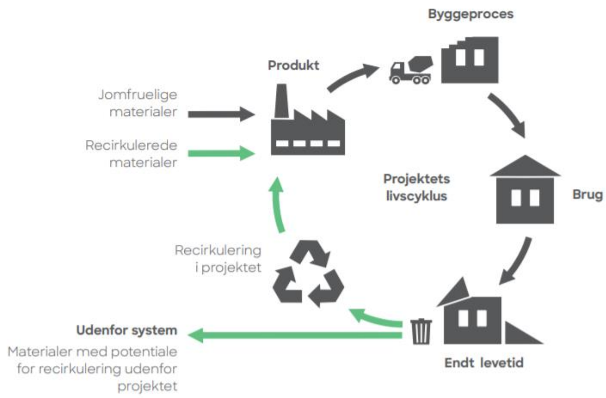

Figure 10 CE in the construction industry (University College 2019)

To have a system that is truly circular it is essential to focus and act on each stage of the life of the product. To obtain a system that is environmentally, socially and economically heathy for C&DW management, five different stages have been identified: "material production phase (new high-grade products with high recycled content), design phase (design for disassembly), construction phase (materials passports),use phase (lifetime extension of existing structures),end-of-life phase (selective demolition) " (2020/1 2019).

When a building is being realized is essential to choose materials that are renewable and not hazardous, or otherwise choose a material that have a high recycled content, with a production processes with low environmental impacts. Additionally is preferable a material which has high durability and therefore have a long lifetime so there is no need to substitute it and throw it away (2020/1 2019).

The design phase is the one that facilitates the recycling of the materials. If the building is designed properly is easier to disassemble the building step by step to repair and reuse the different materials (2020/1 2019). During the Construction Phase is essential to avoid material surplus, and if this is inevitable it is important to find a solution to reintroduce the material in the economy system, for example selling it to another company that could need it. It is also important to have a material passport, which shows the provenience of the materials and their different uses during the life cycle of the construction. This helps to maintain the value of the building and its materials during. (2020/1 2019). During the life of the construction (use phase) it is important to write down what it happened to it during its use and to update the material passport, so to know how to deal with the materials once the construction is demolished, if the material can be reused as it is, recycled or none of them (2020/1 2019).

Once is decided to proceed with a demolition, different actions must be taken up by the different stakeholders. They are identified by the EU Construction and Demolition Waste Management Protocol (EC 2016): it is needed a qualitative pre-demolition material inspection as long with a waste management plan and a decontamination of the built environment is needed if hazardous materials are found. A selective demolition is essential and must be monitored to guarantee the possibility to have hight quality material for their reuse and recycle. It is important to monitor the work actions during renovation work too for the same purpose. The material obtained by the different construction actions must be sorted out with a high degree of precision, it must be traceable and prepared to be reused or recycled. The same material must undergo a quality assessment and obtain the certification of C&DW streams (2020/1 2019).

These strategies must be organized wisely through the business model which can include for example policy support instruments and product-service combinations. Before proceeding with a demolition and select the right technique to use to accomplish the task, some considerations/criteria must be taken in account: the client can impose restrictions on the type and technique that can be used, afterwards the demolition company is the one that choose the right technique respecting the customer willing. The location, as the surrounding and the security of people around the construction are important. The demolition of a high building that is in the centre of a city will use a different technique than a high building located in a not central area. It is essential to have a depth knowledge of the stability of the structure before proceeding, if the structure is found to be unstable during the inspection, is essential to make it stable. Demolition project are usually carried out as quickly as possible, therefore before choosing the technique is essential to take in consideration the time constraint, which is not always imposed by the client, but it can be given by the local authorities. The transport of the waste, as the involvement of structural engineer and his approval are also to be taken in consideration. Finally, the demolition company must take in consideration the possibility to recycle the different material and to do so a selective demolition must be carried, which extend the length of the process and sometimes even the cost (Chimay Anumba 2003).

Even though the CE concept is well known globally in politics, business and academia sectors, the knowledge and tools need to be improved, especially for the construction industry. All of this, with the help of different stakeholders involved during the life cycle of the different materials used, will help to move away from a "take-make-dispose" paradigm to a circular perspective on the regards of material reuse (Eline Leisinga 2017).

2.3.3.The Value chains

Stakeholders are the key to reach a circular system. This report studies the value chain since the writer believes that shifting to a more sustainable system would also give more value to the social dimension. Said so, it is important to say that any type of business is funded through the collaboration of different parties to guarantee the delivery of the product. The whole system is generally composed by manufacture plants, warehouses and sales operations centres which are run by people. The key to have a successful business is to have the different processes to be synchronized and strategically architected within trade-offs (Mawhinney 2013).

As for the business, to have a circular economy system working at its best, is necessary to have the different stockholders and therefore the different processes, to work simultaneously. The right hand must know what the left hand is doing. Michael Porter is the pioneer of the concept of value chain who wrote a book in 1985 called "Competitive Advantage: Creating and Sustaining Superior Performance" in which he explains how companies add value to their raw materials when are producing goods to sell them to costumers. The value chain is used to figure out strategies to cut back on shortages, for the preparation of product plans, and to create relationships among stockholders involved in the whole chain process (Evan 2020).

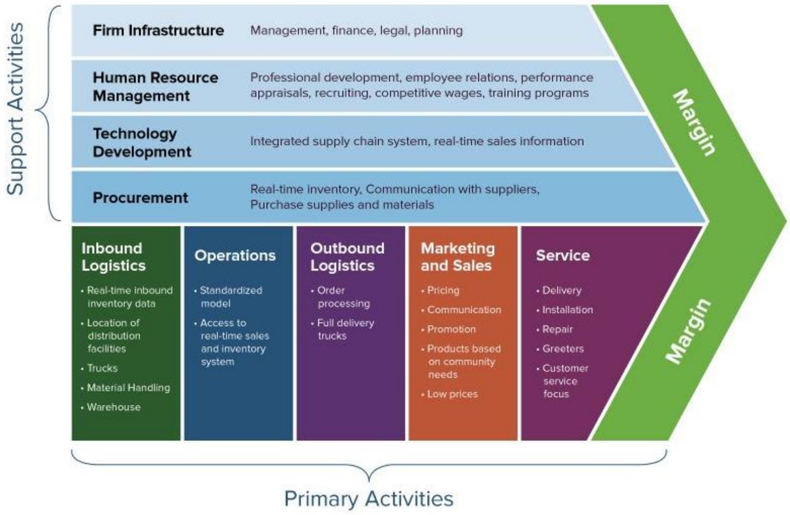

Figure 11 Michael Porter’s value chain (Ahmed s.d.)

The value chain process is composed by five main steps: “Inbound Logistics (Receiving, warehousing, and inventory control), Operations (Value-creating activities that transform inputs into products, such as assembly and manufacturing), Outbound Logistics (Activities required to get a finished product to a customer. These include warehousing, inventory management, order fulfilment, and shipping), Marketing and Sales (Activities associated with getting a buyer to purchase a product), Service (Activities that maintain and enhance a product's value, such as customer support and warranty service)” (Evan 2020).

The have a value chain working at it is best, there is the need of the implementation of technology, procurement, development, infrastructure, and human resource management. It is important to create a connection between the demand and the production. This tool invests in product testing, research and development, innovation, and marketing (Evan 2020). This report sustains, as Porter, the essential of coordination and connection on the horizontal level among internal activities and along the vertical level among suppliers and customers. Linkages are relationships between the way one value activity is performed and the cost or performance of another

2.3.4.1 The Value chain in the bricks market

Each construction project is different for location and type of the project, it can be a building or a civil engineering project of large-scale infrastructure and can be directed by different principles that depends on the local conditions, resources, regulations, purpose and codes that may change over time (International Finance Corporation and Carbon Pricing Leadership Coalition 2018).

In the construction industry is essential to have a holistic approach to define the value chain to have stakeholders developing a strategy together in order to achieve a circular economy system working at its best (International Finance Corporation and Carbon Pricing Leadership Coalition 2018). In the value chain of the construction sector and therefore in the brick market, the stockholders involved are, in order, all the parties that work with extracting raw material, the production of the product, its design, any stakeholder that during the product life will provide maintenance, refurbishment (renovation) to the product, who will take care of its demolition and who takes care of sorting and process the waste. Each of them responds and behaves following the policies set by the governments which can be local, regional, and national scale. (International Finance Corporation and Carbon Pricing Leadership Coalition 2018).

2.4. Life Cycle Assessment

Life Cycle Assessment (LCA) is a worldwide standardised methodology and tool that analyses the impact associated to the life cycle of anthropogenic activities on the environment. This tool helps to make sustainable decisions since it can identify hotspots, environmental benefits and trade-offs of the project that will be realized, making the stakeholders aware of what must be changed and improved (Institute s.d.).

The assessment is conducted throughout four stages: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation of results. A clear definition of the purpose of the study along with the scope and goals, is essential for the outset of the LCA. This will directly influence how to make decisions, the methods to apply to conduct the assessment such as which software tool to use, how much of information have to be gathered and for how long the study will be conducted (Institute s.d.). Once scope and goal are clarified, the next step is the Life Cycle Inventory (LCI). This step works with data collection and is what makes understandable what is involved in the whole system that is being studied. It tracks all the flows that goes in and out the product system, taking in consideration the different phases of the life cycle of the product/project analysed. It is a tool that is difficult to use since it is possible to gather high quantity of data that must be elaborated to be understood. Data and information regarding raw material, type of energy used or needed which is identified by type, water, emissions and use of land can be studied and elaborated with this tool (Institute s.d.).

The next step is given using the Life Cycle Impact assessment which is the phase that evaluates the impact on the environment. A simple example is that during the manufactory process GHG emissions are happening, these data are collected in the LCI phase, meanwhile the LCIA valuates the impact that these emissions can have on the environmental on a decided scale. The LCIA includes the system boundary such as upstream, downstream, and side stream, the functional unit that can be mass, volume, purpose of the and in specific cases is essential to indicate how are impacts assigned to the product and by-products and on what basis (Institute s.d.)

Fig. 12 shows how in the specific contest of construction, the LCA studies and measures all the flows that comes from the nature and are used to realise the infrastructure and its impact on the air, land and water over its lifetime. It is also used to understand the impact of the infrastructure once demolished.

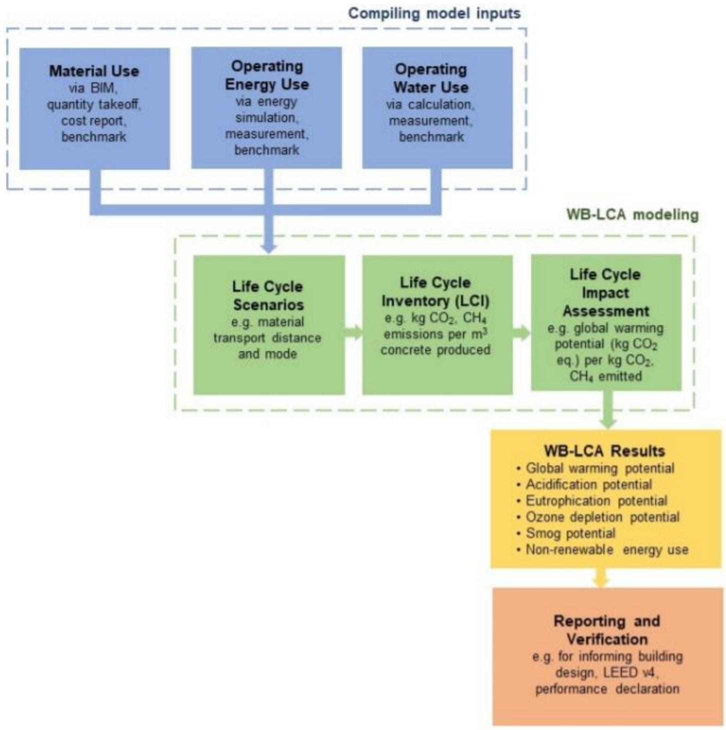

Figure 12 LCA General Flow (Athena Institute B 2019)

Afterwards, there is the phase of "what-if", where the experts can try with redefining the design of the infrastructure, the logistic followed to obtain the final product or repeating the collection data if the result of the LCA is not what was hoped and therefore the impacts given by the realisation of the project is too high (Institute s.d.).

In summary, LCA is complex tool that is used to understand the impacts that a future project can have on the environment. It is realized though the collection of data that represents all the life phases of the infrastructure to realize and it is used to help stakeholders to make the right decision in terms of sustainability (Athena 2019).

3. Methodology

This section describes the process followed to carry out the research to write this report. It is composed by sub-sections which reveal the approaches taken step by step in the paper, the research design, the theory of science and the methodology. The chapter finishes with explaining the sub questions used to develop the report and the methods used to collect information.

3.1. Structure and process

This sub-category illustrates the main structure behind this report (figure 13) as well as the process (Figure 14) behind of it. The aim is to show the layout of the information gathered and placed side by side with the line of thoughts used to write the report. The theme studied is the waste generation given by the construction industry which makes use of limited resource available in the nature and focuses on the use of bricks in Denmark and what it happens to them once become waste. Finally, it aims to find a solution to improve the circularity of the current system.

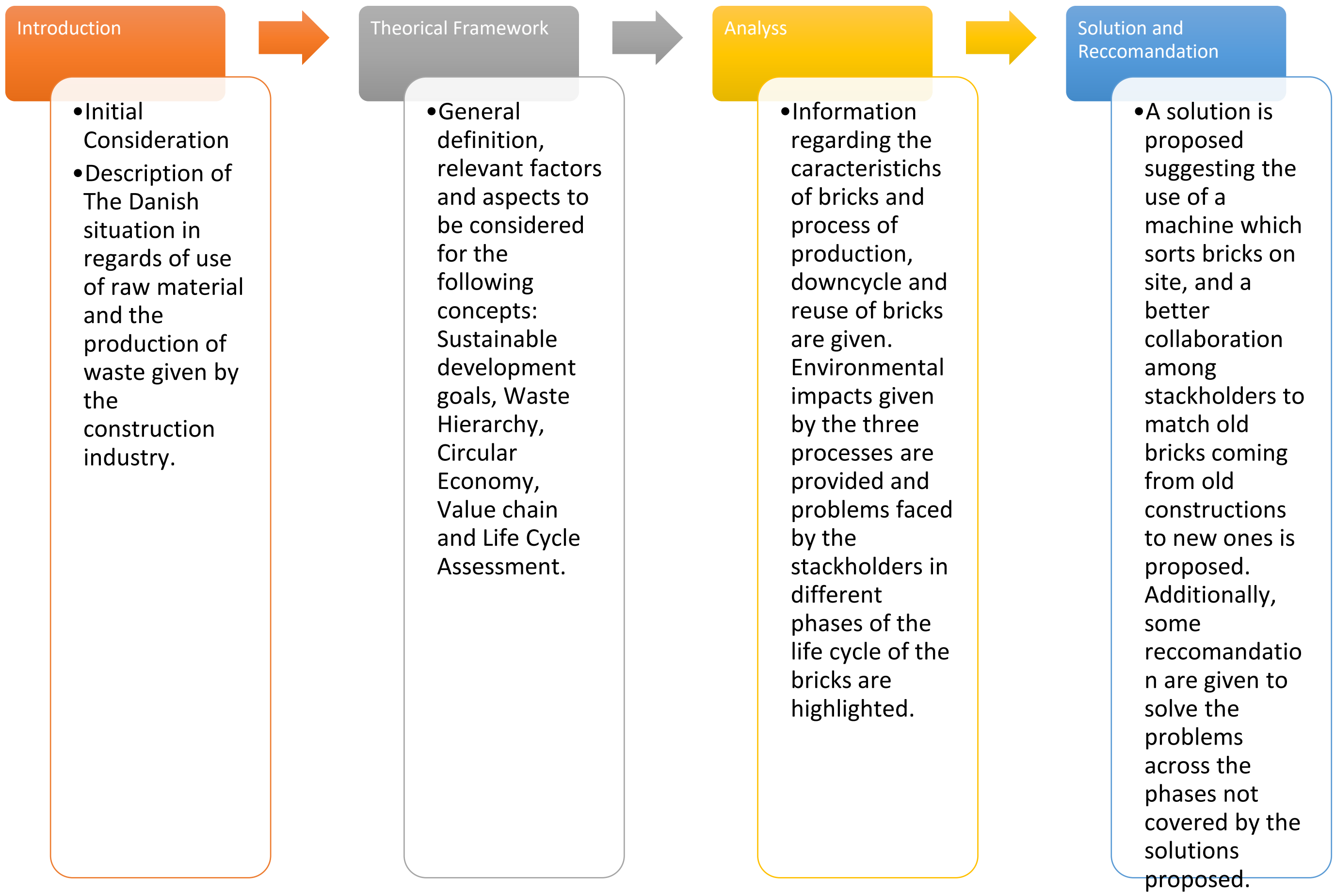

Figure 13 Structure of the report

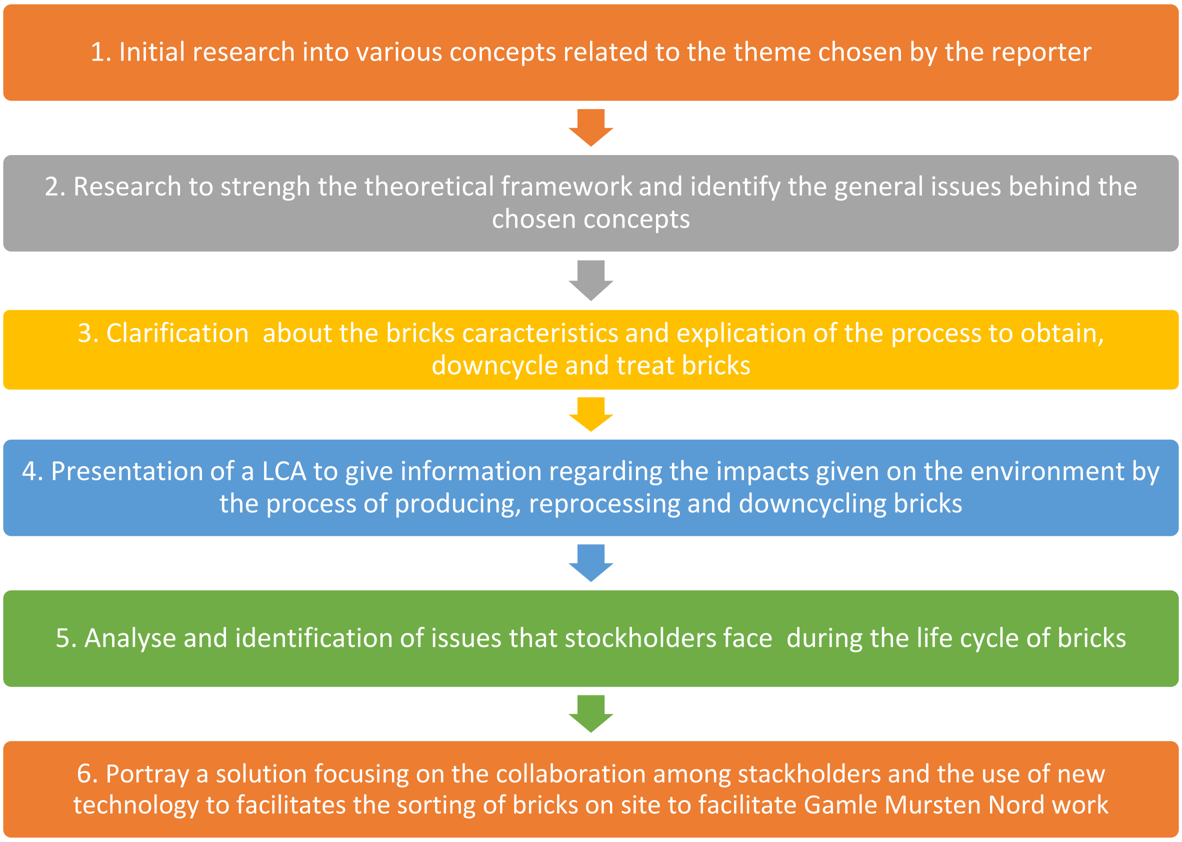

Figure 14 The process followed to write the report

3.2. Research design

3.2.1. Research Overview

Problem Statement
The current construction industry in Denmark is mainly based on a linear system, which makes use of limited natural resources to obtain its final product and eventually become waste as the life of the construction itself ends. The report studies the use of bricks in Denmark, since is among the most used construction material in the country, which once becomes waste is mostly downcycled, a practice that is not considered to be the best sustainable approach available in the market. Every year about 47.3 million bricks could be reused, but only 3 million of them are reintroduced in the market as they are. These numbers show the great potential that this material has in term of sustainability which is not fully exploited. The reuse of bricks could avoid the use of raw material and therefore reduce the impacts of this industry on the environment. A change in the current system is sought and this report helps the purpose of finding a solution to step up on the waste hierarchy and to improve the circularity of the current system to be more sustainable.
Theme
Sustainable Development Goals, Waste Hierarchy, Circular Economy, Value chain and Life Cycle Assessment
Research Question
How can stakeholders in North Jutland enhance the circularity of the current system of the bricks market to become more sustainable?
Sub Questions

1. How are bricks are produced, downcycled, and prepared for reused? 2. What are the potential environmental impacts given by the production, the downcycle and the re-use processes of bricks? 3. What issues do stakeholders face at each phase of the life cycle of bricks? 4. Which solution seems to be the most appropriate to unfold the reuse of bricks and therefore to become more sustainable?
Methods
Literature Review, Collecting Data, Interview

Figure 15 Research Design Overview

3.2.2.General approach

The idea of this report was born because the student became part of the Megaproject 2020 at AAU university. A megaproject is an interdisciplinary project which aims to involve many students to work together on the same topic. All projects focus on global problems involving the UN's 17 Sustainable Development Goals (AAu s.d.). This report works with the category "The Circular Economy", focusing on the possibility to have a circular economy system having as subject the use of Bricks in North Jutland. Unfortunately, it was not possible to collect specific data for the Region Itself, therefore national data was used to reach the solution proposed to be adopted in North Jutland.

The theoretical framework, after explaining the sustainable concept, along with the sustainable development goals, focuses on clarifying the policy tool called Waste Hierarchy and Circular Economy. In particular, the aim of these last two tools is to achieve a better sustainable system which considerate waste a resource to be used and not as something to get rid of. In the same chapter of the circular economy is introduced the explanation of Value Chain since the reporter wants to add a social value to the research. It is believed that the improvement of the waste management in the bricks market will lead to the creation of new job positions and will improve the health of people, since emissions generated by the production and downcycle processes would be avoided. At last, it is presented the tool called Life Cycle Assessment because it is used in the report as technical proof to defend the theory that reusing is more sustainable than producing or downcycling bricks. The writer believes that the change of the current system into a more sustainable one would affect positively the three dimensions (economy, social and environment), but she focuses the analysis on the environment (providing data) and make assumptions regarding the social and economic dimensions since the value chain is being considered during the report. The report also presents a study held by Niras in 2015 which explains the different difficulties faced by the stakeholders during the bricks life cycle that drive them to choose the downcycle or the use of new bricks as final solution. The report focuses its solution on North Jutland and suggests the use of a new technology developed by Gamle Mursten with the help of The Danish Agency of the environment and more engineer companies that allows to sort out bricks on site and therefore to send only the bricks that can be reprocesses to the factory which makes it easier, faster and cheaper to reprocess them. It is also suggested to improve the cooperation and communication among stakeholders working on the same horizontal level across the different life phases using an existing platform to match bricks coming from a demolition site with a new construction in order to close the loop faster and with more efficiency. These two solutions together help stepping up in the waste hierarchy, improve the circularity of the current system and to reduce the impact on the environment. Further some recommendations to solve problems not mentioned in the solution are given, and critical reflection and annexes are provided at the end of the report.

3.3. Theory of science

This paper uses a mix deductive and inductive research approach. The deductive part can be understood from the fact that the report questions the current system regarding the waste management in the

construction industry and its real efficiency. As explained the construction industry make a high use of raw material, which eventually becomes waste once the life of the construction reaches its end, and therefore it is questioning how the current system is managing the waste generated by the bricks market. In this regard different theories are analysed to identify different concepts and tools that can help to shift from a linear system into a more sustainable system. The theories and tools identified are the Sustainable Development Goals, Waste hierarchy, the Circular Economy, and Life Cycle Assessment.
The inductive aspect is present since the report formulates a research question and sub-questions that are born from the mentioned theories to answer the research question which proposes an intervention to achieve a better sustainable system. The research question is the following:

How can stakeholders in North Jutland enhance the circularity of the current system of the bricks market to become more sustainable?

To answer this research question, four sub-questions have been identified and introduced in figure 15. To answer them, literatures were consulted, interviews held, and data was collected and analysed to identify the impacts that the current use of bricks have on the environment and to find a solution to the research question.

The presence of deductive and inductive approaches in the research process shows components of positivism which is the base to generate a research that can be further replicated by others and produce the same results. It follows the school of constructivism since believes that "social phenomena are actually constructed by social actors" (University of Derby 2009) pointing out to an ontology founded on pragmatism which believes that reality can be constantly renegotiated, argued and interpreted and it also underlines that the current values have roots in social and historical background (Patel 2015).

A mix of quantitative and qualitative data was identified, collected using different methods of data collections, such as interviews, statistics, and literal reviews. A full explanation of each method can be found in the sub-section 3.4. All these studies and investigations lead to create the sub-questions and to find a solution to them in order to answer to the Research Question.

In all the sub-questions are used both qualitative and quantitative data. In the second sub-question the quantitative data is more presents and shows a more objective approach creating a link to the positivist theory of science (Patel 2015). Therefore, the answers to these questions are facts and or data which are not subjected by the researcher's belief and not influenced by her thoughts, which limits the subjective perspective and so to portray a point of view. The sub-question one and three are based on qualitative methods presented under a constructivism approach since the first describes processes followed by the social actors on the regards of bricks meanwhile the third one describes the different problems that stakeholders face during the life cycle of bricks, which are given by the current system and imposed by the social context. The fourth sub-question uses qualitative data and it is subjective, since it is used to give a final answer to the research question, and it is believed to be the best solution for the report by the writer.

A high level of subjective can be seen in the theorical framework in which a definition of sustainability, waste hierarchy and circular economy are given along with a definition of Value Chain and Life Cycle Assessment. Each of them has different schools of thoughts, but the writer has specifically used what she thought to be the best suitable school for her purpose. For the waste hierarchy was chosen to follow the indication provided by the European Union, and for the Circular Economy the writer decided to use the definition provided by Ellen MacArthur Foundation (EMF) among the 117 collected by Julian Kirchherr since it is well explained, defined, meticulous and visualised. Additionally, the reporter chooses to find a solution that would lead to step up on the waste hierarchy which aims to have more bricks reused and avoid their production and downcycle. As so, the research was written using a combination of methods to identify the different problems in the bricks market context to find the proper solution and portrayed in sub question four.

3.3.1.Sub-question explanation

To provide a clear, comprehensive answer to the research question, four sub-questions have been identified which can be seen in figure 15 and below. On a general note, the first sub-question offers a state-of-the-art regarding the characteristic that bricks need to be used in constructions along with explanation of the different processes available to produce, downcycle and reuse them. The second sub-question report an LCA which was commissioned by the Danish Environmental Protection Agency that compares the impacts that the three processes have on the environment. The fourth sub question is used to provide a practical solution to the research question which suggests the use of a new technology and the improvement of collaboration among stakeholders over a horizontal level. This sub-section provides an explanation of why these sub-questions are important and how they help answer the research question.

1. How are bricks produced, downcycled, and prepared for reused?

This sub question was thought to explain the three processes of producing, downcycling and reusing bricks. The writer believes that is important to understand the difference among the processes since she assumes that if the reader is aware of how these processes take place, it would make easier to understand how they have different impacts on the environment. It is additionally explained the characteristics that bricks need to have to be used as for the different roles that they can cover in a construction. These characteristics changes on the base of the type of quality of the raw material used and on the production process. It is given the opportunity to understand how raw material is extracted and managed to obtain bricks. To collect this information documents provided by different companies in Denmark that produce, downcycle and prepare bricks for their reuse have been analysed as log with and academic literature provided by AAU.

2. What are the potential environmental impacts given by the downcycle and the re-use processes of bricks?

Here the writer gathers the different data given by the LCA provided by Danish Environmental Protection Agency and is used to provide a better understanding of the different impacts on the environment that the process of reprocessing and downcycling have on the environment which gather the data taking in consideration the different impacts avoided that the production of bricks have on the environment. Using this document, the writer wants to provide a technical proof to show how the reuse of bricks is more environmentally friendly, fact that is also supported by the waste hierarchy policy. Unfortunately, there were not more LCA available redacted in the Danish context to be analysed so the writer took the risk to use as reference only one document, even if dated, since she thought that a technical proof was essential to prove her point. The writer thought that using LCA redacted in other countries could be not the best solution, since each country follows different processes for the extraction of raw materials, for the manufactory of bricks as for shipment of them. In fact, different types of clay are available in the words and differ for land, as for the type of combustible used to cook the bricks. Therefore, using LCA redacted in a different context than the Danish one, would not have been useful and accurate. Additionally, during the different interviews the theme of technologies used and the pollution generated by them was brought up by the experts and it seems like that they have not been changed that much over the time, in fact the main fuel used nowadays to fire up the new bricks is still the natural gas, same as the one taken in consideration by the LCA used in this sub question.

3. What issues do stakeholders face at each phase of the life cycle of bricks?

This sub-question reports information provided by a study held by NIRAS in 2015 which interviewed different stakeholders involved in the value chain of the bricks life cycle and made a list of problems that drive them to buy new bricks or downcycle them instead of reprocessing them for their reuse. This sub question helps to understand where these problems lay so the writer and the reader can have a better idea of what must be changed in the system. Different problems were found for each phase of the life cycle, each of them has in common problems connected to time, the economy and logistic aspect, and is highlighted a lack of knowledge regarding the characteristics and the use of old bricks. This sub question is the base that provides the base for the proposed solution.

4. Which solution seems to be the most appropriate to unfold the reuse of bricks?

After have learnt how bricks are produced, downcycled and prepared to be reused, their characteristics, which stakeholders are involved in the different phases of their life, what are the problems faced by the stakeholders that drive them to downcycle the bricks instead of reprocessing them or to use new bricks, and showed how reprocessing them has a minor impact on the environment if compared to the downcycle and production processes, the writer decides to focus and suggests a practical solution which makes use of a new technology developed by a collaboration between Gamle Mursten and the Danish Environmental Protection Agency which was thought to improve the sorting of bricks on site, that would avoid the transport of unnecessary bricks to the factory making the transport cheaper and the their reprocess at the factory easier. This solution is thought to be the best by the writer since it can be introduced in the nearby future, can be implemented faster and is cheaper than other solutions that could have been proposed. The solution focuses on the North Jutland area since takes in consideration the factory Gamle Mursten Nord (which has some differences in organization from Gamle Mursten) and the region strategic plan released in 2018. Additionally, a collaboration on horizontal level among stakeholder is suggested to step up in the waste hierarchy and improve the circularity of the system. This collaboration can be achieved using the already existing platform Business Region Denmark (BRN) on which old bricks can be matched with new constructions so to close the loop and guarantee an economic income as the creation of job opportunities. Unfortunately, it was not possible to portray an analysis using quantitative data, but the solutions mostly uses subjective assumptions given by the study of qualitative data available about the technology proposed as solution.

3.4 Methods of data collection

This report uses a mix of quantitative and qualitative methods. The qualitative data was collected through literature and national, regional, and local plans reviews, interviews, and consultancy of companies' websites. On the other hand, the quantitative data was collected by gathering raw data from different databases.

- Literature review as an inductive-qualitative method was used to build the theoretical framework which helped to shape the problem formulation and the research question within the sub questions. It helped to frame the theoretical background that guided the problem formulation and to develop the research question, as well as contributed to the final solution. The research used various types of literature reviews provided by AAU library and companies' websites such as Gamle Mursten and AVV. Additionally, the writer used information provided by the European Environment Agency, specifically the ETC/WMGE 2020/1 to have a better understanding of the life cycle of a building and how the waste hierarchy works and which are the different principles followed by it. The document also provides some information of how to achieve a circular economy system in the construction industry. An LCA redacted by the Danish Environmental Protection Agency was studied and analysed to understand what the impacts given by the process of production, reuse and downcycle of the bricks are, considering different variables. The regional strategic plan for North Jutland was also used, which was used as base to propose part of the solution.

- The data were collected using the web site Statistics Denmark and further used through the whole report. Some data were also collected through the LCA, companies' websites, national, regional, and local plans.

- Three people were interviewed, more were in the agenda, but due to the covi-19 it was not possible to reach who was in the list. The first Person interviewed was with Svend Roed Larsen, he is a consultant working for Randers Tegle in Aalborg who oversees relationships with new costumers and with whoever is in interested in the brick market. Questions regarding the process of production of bricks and technologies used were asked, additionally were posed questions regarding who are the stakeholders that do business with them. It was also asked how the business works and what he thought were the reasons that drive stakeholders to use new bricks instead of old one.

The second interview it was with Claus Juul Nielsen the Director of Gamle Mursten in Svendborg. Questions regarding the process of cleaning were asked, what are the trouble faced by them during the reprocessing phase. As for Svend it was asked what was the logistic followed by them, who are the stakeholders that use their service and if it was up to them to collect the bricks from the site. Additionally, it was asked why there are not so many factories in this business and what does he think on the matter of helping provided by the government in terms of taxes or incentives. It was also asked information regarding the technology proposed in the solution to sort bricks on site, since his company worked on its development. Unfortunately, not all the information needed were provided.

The third person interviewed is Kurt Brandi, the head of department of Gumle Mursten Nord-AVV. Questions regarding the partnership between AVV and Gumle Mursten were asked, information regarding which are the problems that North Jutland faces in reprocessing the bricks were asked and questions about how they contact their costumers and how they deal with the transport of bricks were asked.

4. How are bricks are produced, downcycled, and prepared for reused?

To begin the study is important to understand what are the raw materials used to obtain the bricks, what is the process followed to produce, downcycle and reuse them, and what are the different physical characteristic and roles that they can cover in constructions. This information would give the reader insights of how the three processes can impact the environment, the society and on the economy dimensions, and what characteristics must the bricks have if they want to be reused once they have satisfied the role that they were produced for. It is also important to specify that the bricks characteristics change on the base of the process followed when manufactured, therefore is important to have such knowledge, since bricks must conserve these specific characteristics once reprocessed.

4.1. General information

Bricks are an old and well-known material used in the construction industry. In Denmark, there are examples dating back to the 12th century (Videncentret Bolius 2019). As mentioned, clay is the raw material used to produce bricks. The mineral must have specific proprieties and characteristics such as plasticity, which allows to mould and shape the clay once mixed with water and it must have enough wet and air-dried strength in order to maintain the shape once the brick is formed (Brick Industry Association 2006).

4.2. Raw Material

There are three different type of clays, with similar chemical composition but with different physical features:

- Surface clay belongs to old or recent found agglomerate, they are localised nearby the surface of the earth.
- Shales are a type of clay that have been subjected to high pressures until they become so compacted and slate.
- Fire clays are found at the deeper levels of the earth if compared to the other types and have refractory qualities.

(Brick Industry Association 2006).

The surface and Fire Clays have a different physical structure from shales, but as mentioned above, they are similar in chemical composition. The tree types contain silica, alumina, and different amount of metallic oxides. The latter help the fusion of the particles even at lower temperatures and influences the final colour of the bricks. The difference among the clays are minimized by the manufacturers who can also mix up the different type of clay during the whole process of production. The chemical composition keeps changing in the different phases and at the end of the production, even if the bricks come from the same manufacture, will have slight different properties (Brick Industry Association 2006).

4.3. Properties

The type of raw material used, and the process followed to produce the bricks are the responsible for their physical properties. It is a common action to mix up the different clays to obtain the product desired and to improve the overall quality of the finished product. Each brick has the following proprieties: durability, colour, texture, size variation, compressive strength, ability of absorption, salt, and frozen resistance. Here an explanation for each of them is given (Brick Industry Association 2006).

The durability it is given by the right combination of incipient fusion and the possibility to reach partial vitrification during the firing. Along with compressive strength and absorption is used to understand how long the brick can live. It depends on the chemical component of the brick, on its compressive strength, ability of absorption and on salt and frozen resistance (Brick Industry Association 2006).

The colour of bricks is given by the chemical component, the fire temperature used, and the methods used to control the fire. For example, if the clay contains iron, the brick will have shades of red if exposed to an oxidizing fire. Here the chemical interaction creates ferrous oxide who is considered to be the responsible of red shades. If the same clay is fired in a reduced atmosphere, the final product will have a dark tone. Brick with darker colour will be cooked in higher temperature and as result will have a hight resistance to absorption and higher compressive strength. The chemical components are also responsible for the malleability of the clay and it is directly connected to the other proprieties listed (Brick Industry Association 2006).

A smooth texture is the result of pressure used by the steel die as the raw material passes through the extrusion process. Bricks with damaged skin are treated to have this surface removed and further a new texture is produces on the surfaces using devices that, in order, cut, roll, scratch and brush the surface or make the surfaces roughen. Slurries or ground clay or colorant are used to redefine de façade. If patterns on the bricks want to be created, it is added sand in the different phases of production. Instead the glazing bricks are obtained using ceramic, which is add, as for the sand, during the process of production. There are two variations of glazing: single fired where ceramic is sprayed on bricks before or after drying and afterword kiln-fired using a regular temperature. The second is the doubled fired which applies ceramic after the brick has been fired and cooled and then fired once again at a temperature lower than 982°C and is used to obtain colours that are not possible to produce using higher temperature. Glazes are resistant to water and vapour (Brick Industry Association 2006).

High compressive strength value correspond to a lower absorption value and they can be controlled by temperature and process of manufactory, but these two proprieties are also connected to the properties of the raw material used to obtain the bricks (Verner Bjerge 2016).

The frozen resistance is calculated and respected on the base of environment in which is being used. There are three possibilities: the first one is needed when the brick is exposed to a severe environment exposed to saturation and subjected to repeated freezing and melting situations and therefore is required a high durability. The bricks used in facades are often required to respect this type of resistance. In the second case, the brick is in a saturated environment and there is a jump from frozen to melting states. This case is different from the one because here a brick will not be able to survive extreme environment. The last one regards bricks not exposed to freezing environment. Bricks with this resistance are used only for internal use and if stored, during the winter they need to be protected (Local Architects Direct s.d.)

Salt Resistance has three categories. The first salt resistance guarantee bricks resist to water penetration, the second one it has limits on specified soluble salt sodium, magnesium, and potassium contents. The last category of resistance has a limited salt contents and it goes from Normal (N) to Low (L) (Local Architects Direct s.d.).

4.3.1.Size

The standard size of bricks is different for each country. The standard dimensions in Denmark is on the long side 228 mm, on the short side 108 mm and 54 mm in height (Murstensguiden.dk s.d.).
There are three different types of bricks: the Massive mursten which does not have holes, the solid brick which has a percentage of holes of less than 25% and the cell stones which has a percentage of holes between 25% and 70% (Murstensguiden.dk s.d.).

4.4. Use of Bricks

Bricks can be used in different context on the base of their characteristics and properties. High-quality bricks with standard shape, smooth surfaces, sharp edges, great strength and high durability can be used for permanent structural construction such as buildings, bridge piers, dams, roads and pavements (The Constructor s.d.).

In regards of walls they can be used in foundation, fences, exposed brick walls, not exposed bricks wall, retaining walls, arches, and cornices. They are also used for decorative purposes, and as said, can have different colours. The bricks that are overcooked have a temporary use in structures and must be not used where there is heavy dampness and frequent rain. Low quality bricks can be broken easily and therefore are used in foundation concrete and road works as aggregate and finally bricks can be used for aesthetic purposes (The Constructor s.d.)

4.5. Manufactory

The process of manufacturing starts with digging up the clay which influences the possibility to have a high-quality final product. The excavation technique itself can often have an impact on the quality of the clay, on its homogenization and deformability. During the extraction, the clay starts the natural process of drying which can influence the final product with the result of cracks. Today almost exclusively hydraulic excavators and towers are used to dig up clay (Verner Bjerge 2016).

Figure 16 Extraction of Clay (Verner Bjerge 2016)

Once the clay is extracted, it is driven directly from the clay tombs to the machining machines, but it can also happen that the clay is stored before being used in production. The storage takes place either under open skies or in covered pits, the so-called dump houses. The clay is often laid in layers using a conveyor belt, on which different types of clay can be mixed or other materials such as sand or sawdust, add. There are two main reasons to store the clay: first, the production depends on weather conditions. Previously, the production had to stop during the winter months and during rainy periods since it was difficult or impossible to dig the clay and transport it from the clay pit to the brickwork area so it was essential to have a stock of clay during these times if the production had to continue. Second, if the clay is stored, the raw material can be mixed and blended in a better way to obtain a better final quality (Verner Bjerge 2016).

When the clay is brought from the clay trench - usually by truck - or from the clay warehouse to the actual machining, it often passes into a mixer which is open and has one or two longitudinal slowly rotating shafts with tight-fitting inclined blades. The clay is processed and cut by the blades and follows the movement of the blades pushing it forward from the filling funnel until the end point of discharge. In the mixer the consistency of the clay mass can be regulated either by the adding water or dry clay powder, which is usually made by crushing dried clay raw stones in the mix (Verner Bjerge 2016). A box feeder is installed at the beginning of the mixer to have uniform material. A box feeder consists of a stretched box that has a conveyor belt at his bottom. The material is transported by the belt which pass through a sieve so that material of a certain thickness is transported out of the box. Doing so it is ensured that the material transported into the mixer is approximately the same diameter. If several materials are to be mixed (sawdust, sand, grease, lean clay), a box feeder is usually used for each material (Verner Bjerge 2016). Steam is spread onto the clay throughout the mixer, raising the temperature of the clay mass to increase the formability. The fact that the temperature of the clay mass can be raised by the addition of steam also means that the newly formed products can dry faster and easier. Gas burners are installed in the plants to be used in the case the condensation of vapor causes problems since the clay can get too wet. Afterword, due to the evaporation, a small reduction in the clay's water content can occur (Verner Bjerge 2016).

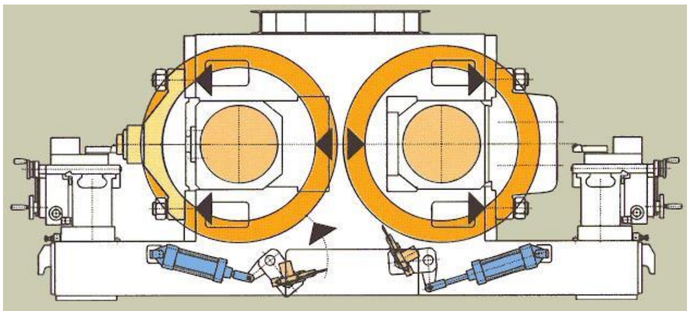

Figure 17 Rolling Mills (Verner Bjerge 2016).

From the mixer, the clay is transported to a rolling mill which may have one or more pairs of steel rollers. One of the rollers may be stone separating, which has at its base a helical elevations or threads that shoot stones that cannot pass through the space between the rollers. The rollers can rotate with different speed and can be set at such small distances that smaller stones or limestone are crushed (Verner Bjerge 2016).
After the machining is done, the tiles can be formed using two methods: hand ironing, soft ironing or string pressing. To be shaped, the clay, must have the right water content. For the different Danish clay varieties, this water content varies along with clay and with the method of preparation, for example hand and soft ironing require greater water content than string pressing. In general, the water content of newly formed products is 20-30% by weight (Verner Bjerge 2016).

The hand Ironing is only used by a few of productors and the brick is formed by hand. With this process are also manufactured roof tiles. These products are mainly used for restoration of old buildings and is a process completed by hand. Clay is poured into a pre-moistened wooden frame, then the excess clay is ironed with a ruler and the frame is turned onto a board (patch) and lifted off whereupon the stones are ready for drying. Due to the method of manufacture, the bricks obtained out this method are never smooth and they are often used as facade stone (Verner Bjerge 2016).

The soft Ironing or string pressing has the highest demand and are being produced using machines that imitated the hand-ironing method. The clay is pressed into a formwork and then deposited on steel plates, on small boards or on laths, which automatically transports away the shaped stones away from the machine once the job is completed. There are different machines that can be used for this process, but the most used and known is the soft stone press and the bricks obtained using this machine have a smooth surface (Verner Bjerge 2016).

Figure 18 Soft press machine shaping the bricks (Verner Bjerge 2016).

Figure 19 Soft press machinetransporting the bricks (Verner Bjerge 2016)

Once the products are shaped, they are dried. In modern brickwork, the transport from design site to drying place is automated and usually takes place by depositing the bricks on laths and placed on shelves in a magazine (Verner Bjerge 2016). Water must be removed from the bricks during the drying phase before burning them. The evaporation given by the chemical processes, which also produce a slight reduction in size of the bricks. The linear drying shrinkage of the various Danish brickworks mainly ranges from approx. 2% to approx. 7%. In the drying plant, it is possible during the entire process to regulate the temperature, the humidity of the air and the speed of the air - which determine the course of the drying, so that the products can dry in the shortest possible time without cracking (Verner Bjerge 2016).

The heat used in a drying plant is usually a surplus heat from the furnace, optionally supplemented with a heat from a gas burner. Normally it takes around 2-3 days for the bricks to dry properly (Verner Bjerge 2016).

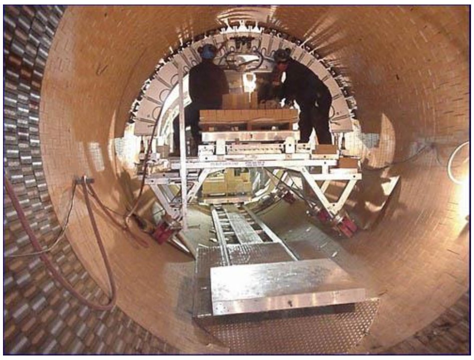

Figure 20 Kiln to fire up bricks (Bricks Solution s.d.)

Once the bricks are dried, they are burnt in a kiln for around two days. This happens during the firing phase which provokes chemical and physical changes. Danish clay species burn between 950-1050 °C and melt between 1000 and 1100 0 C. During the firing it is possible to regulate the temperature and the furnace atmosphere can be controlled. The kiln is a tunnel, the bricks are loaded on wagons that run along it. In the first part of the kiln, the products are heated then fired up and the end cooled down before leaving the tunnel (Verner Bjerge 2016). Nowadays the kilns are fed using natural gas. The gas is injected into the furnace following short intervals. It is possible to regulate the amount of gas, the pressure, and the interval of the gas release. The burning process is monitored from a control room and temperatures are recorder (Verner Bjerge 2016).

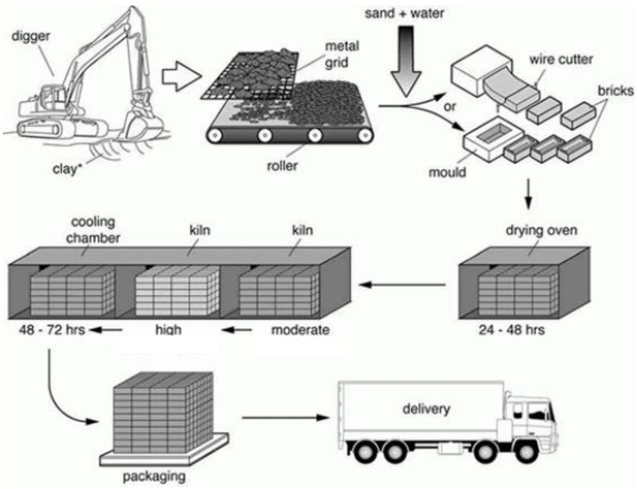

Figure 21 Process followed to obtain Bricks (Suryakanta 2014)

4.6. Methods to Downcycle bricks

The downcycle of bricks consist on the simple action of crushing them using a machine. The crushing can be done on the demolition site as long it has been declared a safe environment in which nobody will get hurt or on the company's waste management sites. The transport can either be organized by the crushing company (which asks for a payment for the service) or by the stakeholders that owns the bricks. The bricks are inserted in a machine that has a jaw and chew them and it is possible to decide the size of the debris on the base of the needs. Further the bricks crushed are mostly used as filler in other constructions such as roads (Hvidberg s.d.). This practice is located on the recovery step along the waste hierarchy, and it does not follow the principle of CE, since the same material could be easily reused as it is with some extra treatment instead of being crushed so it is considerate not to be the best sustainable solution which does not help the purpose of reach a circular economy system (2020/1 2019).


Figure 23 Example of machines that crush bricks (Möckeln Svenska AB s.d.)


Figure 22 Example of jaw where bricks pass through out to be crushed (Recycling Industry 2016)

4.7. Methods available to prepare bricks for their reuse

Nowadays in Denmark the stakeholders largely prefer to downcycle the C&DW since is cheaper, faster and because the material sometimes do not hold the needed physical and aesthetic characteristics to be reintroduced in the market (Nielsen 2020). The possibility to increase the rate of reusability of bricks starts from the beginning of their life. The building that is using bricks should be designed to be easily dissembled during its life, and at the end of it, the same material dissembled should be reused in other constructions. The bricks should have a passport in which is described their provenience and the different maintenance that they went through during their life. Finally, a selective demolition is the key to process them for their reuse. To ensure that the bricks move on for reuse or recycling, it is required to upload a request in the demolition tender material (2020/1 2019). Once the bricks are sorted on the site, they are transported to the factory and treated. Here is given the explanation of how Gamle Mursten treat old bricks to be reused since it is the only company in Denmark to provide bricks with the CE certification which is the result of a well-studied and developed technology that is owned by the company. Gamle Mursten is the biggest company in country that processes brick having access to a bigger capital and can reprocess around 18 000 bricks for day. Smaller Businesses such as Salling Entreprenørfirma, are cleaning bricks by hand and can reprocess about 70% of the bricks that receives but they can't provide CE certification for their products. Salling produce can treat around 250 bricks for day for every two men (Niras 2015) .

Figure 24 Brick being prepared to be reused – Gamle Mursten machine (Gamle Mursten s.d.).

Gumle Mursten developed a patented technology where bricks are cleaned mechanically using vibration technology, as showed in figure 24. This vibration removes the mortar and neither water nor chemicals are included in the process. After cleaning, they sort and proceed manually to check the quality, the type and the colour, weight, sound, texture and resistances, characteristics needed if the bricks want to be reintroduced in the market. The cleaned bricks are then placed on conveyor belts that lead them to a robot that stacks and packages the bricks according to customer requirements. Bricks that can be exposed to weather conditions are kept separated by the one that can't be exposed. This business only clean bricks that are lined with lime mortar. In the case the bricks are lined with cement mortar, the cleaning is more difficult, since the cement is harder than the brick itself and therefor, during the process, the brick brake before the cement (Gamle Mursten s.d.).

Up to 65% of the bricks that are arriving can be reused but this depends a lot on the quality of the demolition. In the past Gamle Mursten was disposing the damaged bricks but they come up with a new way to make no reusable bricks operable. The damaged brick is cut along the thickness 25 mm which gives the possibility to achieve a utilization rate of up to 80% of the material that comes in the factory for cleaning. The decomposition and the subsequent cleaning process give the bricks a rustic surface, additionally it has been tested that the process does not affect the quality of the bricks. Bricks can be also personized if requested. Gamle Mursten also offer the possibility to customize the bricks and it cut them following the desire of the clients (Gamle Mursten s.d.).

Figure 25 Bricks cut and customized by Gamle Mursten (Gamle Mursten s.d.)

Using this technique of cutting, Gamle Mursten introduced a new way to make use of old bricks. They are attached to a slab to create a module which can be assembled and screwed on an existing wall to give a rustic aspect to the environment in which is installed. The module is 40 cm in height and 60 cm in width and can be used for internal and externa (exposed to weather) purposes (Gamle Mursten s.d.).

Figure 26 Module system provided by Gamle Mursten and composed by cut bricks (Gamle Mursten s.d.).

Before demolishing a construction, an analysis of the building is done to assure that hazardous material is not present, among other reasons. Doing so is also possible to understand the quality of the bricks which is an advantage for the company that is taking them. This is especially important when thousands of bricks are being delivered so the factory can have a better idea of what they will receive and how to store them (Gamle Mursten s.d.).
Bricks can be reprocessed to be stock up in a warehouse and further bought by stakeholders, reused in the same construction once cleaned when the infrastructure is going under a restructuration or in the best case, the bricks coming from a demolitions site have been already bought to be reused in a new structure, which close the loop of material usage (Niras 2015).

The reuse of bricks would help to reduce the extraction of primary raw material to add value to the material used to produce the bricks reused and to reduce the energy consumption given by the production of new bricks, since the energy saved every year is equal to the same energy used by 3000 houses in Denmark (Gamle Mursten s.d.)

4.8. Conclusion

Bricks can have different physical and chemical characteristic, which gives products with different texture, durability, size, strength, frozen and sault resistance, and allows them to have different roles in the infrastructures. These characteristics are influenced by the process used to produce the bricks and are needed if the bricks are being reintroduced in the construction market once they have satisfied the role for what they were born. The explication of the three processes of producing, downcycling and reusing are different under different aspects, and it helps to understand how they can have different impacts on the environment since they make different use of material, energy and technology among various aspects.

5. What are the potential environmental impacts given by the downcycle and the re-use processes of bricks?

This sub question helps to have a better understanding of the impacts that the reuse and the downcycling of bricks have on the environment. This section provides lifecycle-based environmental assessment (LCA) that was carried out for the Environmental Protection Agency of the Department of Environmental Engineering (EPA) between 2012 and 2013 period as part of a service agreement between EPA and Technical University of Denmark (DTU) on research-based services within the waste sector. Are used impact categories such as abiotic resources (fossil and elements), included categories for human toxicity and not toxic elements. The LCA includes the environment impacts avoided that the manufactory of new bricks would provoke, along with the transport and the process of sorting. The final disposal of any residues from the treatments and it takes in consideration the exchange of material and energy that the surrounding production system would use (Miljøstyrelsens 2013).

The reporter is aware of the uncertainty that comes from using only one document as reference. Although other LCAs with bricks as subject were not available in the Danish context, and it was not possible to use other LCA wrote in other countries, since processes of material extraction, the production process and technologies in the different processes, change by country. The writer thought that it was essential to provide technical information about the environmental impacts given by the two processes to support the theory highlighted by the waste hierarchy policy and the circular economy that the reuse of bricks is more sustainable than their production or downcycle.

This LCA consider only the bricks that by law can be reused or recovered and therefore put back in the market. It is therefore modelled with scenarios where bricks are downcycled and processed to be reused in an exposed and not exposed context to weather. It also includes the transport of them to the different locations, the action of sorting the bricks and includes the use of substances used for different treatment and GHG emissions. Through the whole LCA the production of bricks is constantly taken in consideration so that at the end is possible to show how the reuse of bricks has less impacts on the environment then the downcycling and the production of new bricks which support the purpose of this report to improve the circularity of the system through the use of waste hierarchy policy to become more sustainable (Miljøstyrelsens 2013).

The production of bricks involves different processes starting from the use of land which prevents the use of it for agricultural purposes or any other purpose and accelerate its degradation. During the production process of bricks since the extraction, until the disposal, greenhouse gases (GHG) are emitted into the atmosphere. The kiln used to fire up the bricks emit toxic fumes which are dangerous for longs throat and lungs because they contain carbon monoxides and Oxides of Sulphur (SOx) along with carbon particles. These emissions pollute the air and are considerate to stop children growth both mentally and physically. The production of bricks is the second industry that emits more SOx emission in the atmosphere (Deepasree M Vijay 2011). Additionally the production of bricks generate emission of Hydrogen fluoride (HF) and Hydrochloric acid (HCl) which are considerate to be toxic either for humans and environment (Miljøstyrelsens 2013).

For each brick not produced, 500 grams of CO2 emissions are saved, which means that for an average house that uses 16 000 bricks, 8 tons of CO2 are saved if old bricks are used in the construction (Gamle Mursten North s.d.) . The quantity of clay used to produce bricks exposed and not exposed to weather is the same, but emissions are slightly different, since the bricks exposed to weather needs a higher degree of hotness when fired up (1000-1050 °C, meanwhile the ones not exposed are fired at 800-900 °C). The production of bricks exposed to the weather emits more CO2 which is the result of the use of more fuel to reach higher temperature. In this case 113.9 kg por ton of bricks produced is emitted versus the 103.8 kg per ton. SO2, NOx and particle have the same quantity of emission, meanwhile the emission of HF is 5 times higher (42.1 g for ton vs 8.4 and it is considered the use of natural gas as combustible) (Miljøstyrelsens 2013).

The LCA presents 3 different scenarios: scenario A consider 100% of bricks waste recyclable (downcycled), scenario B and C consider that the 64.5% of the brick waste received is reusable and the rest is processes to be downcycled. The difference lays on the fact that in B the bricks are treated to be used in facades so exposed to good and bad weather, meanwhile in C they are used in contexts not exposed to weather and therefore used in closed environments. Residual waste, which consists of sand, mortar and non-reusable bricks are transported to crush site and treated as in scenario A (Miljøstyrelsens 2013).

A functional unit is used to gather the data in all the scenario and is considered one ton of bricks waste which contains a certain amount of bricks that fully - technical and functional - can replace new bricks exposed and not to weather (64.5%) (Miljøstyrelsens 2013).

Data is collects with the help of companies that work in the brick’s market which agreed to provide information about the different processes and what needed to redact the LCA. Here are taken in consideration data provided by Gamle Mursten A / S, as mentioned the biggest company in Denmark that

works with reprocessing old bricks into the market, by RGS90 a company that among other things, deal with downcycling bricks and Kalkog Teglværksforeningen that produce new bricks. For data that were not possible to get from these companies, this LCA used data recognized by other different LCA database (Miljøstyrelsens 2013).
Only 4 of 12 impact categories were taken in consideration since for the rest of the categories, the level of uncertainty was to hight or the valour of naturalisation was too small to be taken in consideration. The potential environmental impacts were normalized and calculated in milliseconds (10-3) personal equivalents (mPE) per ton of brick waste. One-person equivalent (PE) corresponds to the average annual load from one person in the environmental impact category concerned (Miljøstyrelsens 2013).

Figure 27 shows the total non-toxic potential environmental impact of recycling (Scenario A) and re-use (Scenario B and C). In scenario B there is a potential environmental saving of -13.4 mPE / tonne waste brick. This corresponds to -103.6 kg CO 2- equivalents / ton brick waste. Instead, in Scenario C, the potential environmental saved is less than the scenario B and amounts to -6.8 mPE / tonne brick waste, which corresponds to -52.6 kg CO 2- equivalents / ton brick waste. The scenario A leads to a small net potential environmental impact of 0.6 mPE / tonne waste bricks equal to 4.5 kg of CO2 equivalents / ton brick waste. The reason why Scenario C provides less potential environmental savings, is given by the fact that the production of the bricks used internally uses lower energy than the production of bricks used outdoor (Miljøstyrelsens 2013).

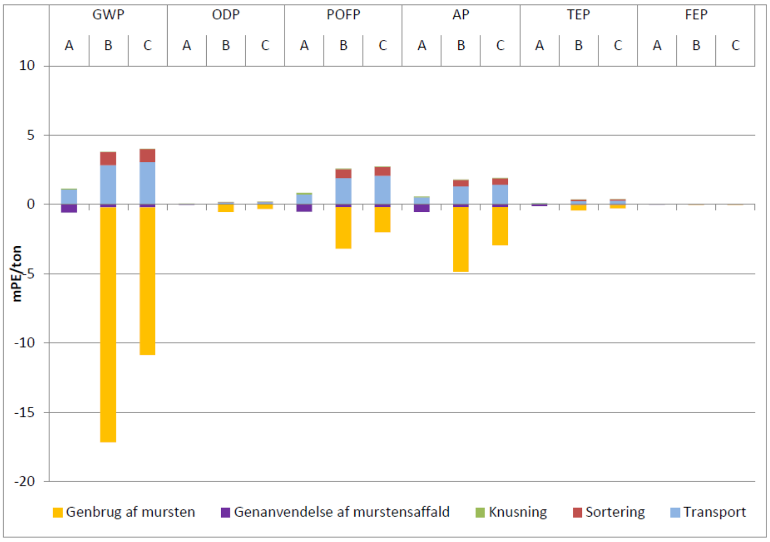

Figure 27. NON-TOXIC POTENTIAL ENVIRONMENTAL IMPACTS MEASURED in milli PER TON BRICKS WASTE BY PROCESSES IN RECYCLING SCENARIO (A) AND REUSE SCENARIOS (B, C). GWP: greenhouse effect, ODP: ozone depletion, pofp: Photochemical ozone formation, AP: acidification, TEP: terrestrial eutrophication, FEP: FRESH EUTROPHYING (Miljøstyrelsens 2013).

The potential environmental impacts on transport are greater in reuse than downcycling and is given by the geographical location of companies studied in the scenarios. In scenario A, the transport process consists of transporting crushed brick waste to road construction, which is in average shorter than the one covered by scenario B and C, since there are a few factories that treat old bricks to be reused in Denmark (Miljøstyrelsens 2013).

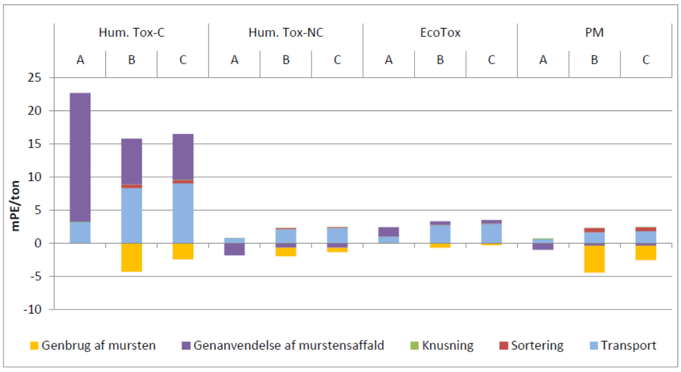

Figure 28 Total toxicity potential environmental impact MEASURED IN Milli per ton BRICK WASTE RECYCLING In scenario (A) and the reuse scenarios (B, C) HUM. TOX C: toxicity (CANCER EFFECTS), Hum. TOX NC: toxicity (NON-CANCER EFFECTS) ECOTOX: ECOTOXICITY PM: PARTICL (Miljøstyrelsens 2013).

Figure 28 shows the normalized values for the potential toxic environmental impacts distributed processes included in the scenarios. The processes "Transport", "Sorting" and "Crushing" contribute all with net environmental impacts in the toxic impact categories, of which "Transport" in all categories are the most significant process. On average, the downcycling process is the one that have a bigger toxic potential impact on the environment and therefore on the social context. This is mainly due to leakage of heavy metal chrome from the crushed brick waste used for road construction. It is seen that the environmental impact of this process is less in the reused scenarios, where only 35.4% of the weight is crushed for road construction. On the other hand, the environmental impact of transport is use of the fuel used by the trucks to transport the bricks (Miljøstyrelsens 2013). It is important to specify that differently from the non-toxic data collected, the toxic environmental impact categories are associated to uncertainty since they depend on different characterization factors as well as normalization. Therefore, it is not safe to say that the toxic and no toxic scenarios are significantly different. Told so, the data in figure 28 can't be used to rank the scenarios in relation to the potential toxic environmental impacts but it can be used to have a general idea of the toxicity (Miljøstyrelsens 2013).

Consumption of abiotic resources in the form of fossil fuels and elements such as natural gas, metals etc. are shown in Figure 29. The resource consumption of elements is very limited and lies below 0.2 mPE / ton of brick waste for all scenarios (Miljøstyrelsens 2013).

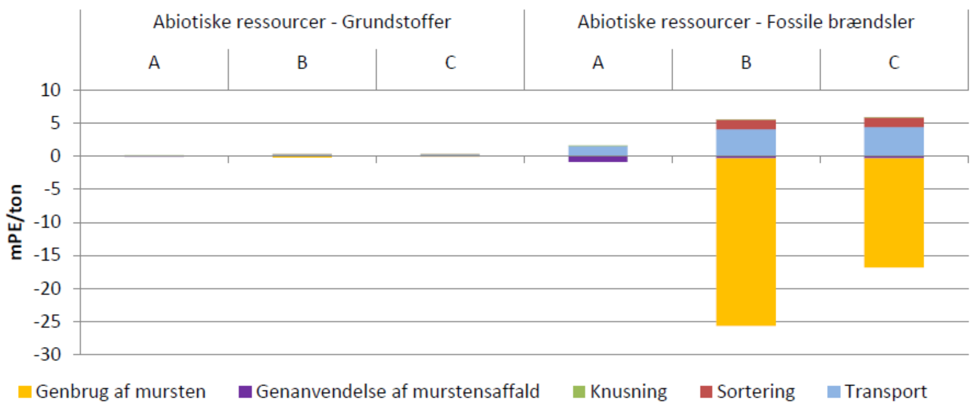

Figure 29 Consumption of abiotic resources (Miljøstyrelsens 2013)

It is possible to see that there is a difference between the consumption of fossil fuels. In scenario A there is a 0,8mPE consumption, whereas in reuse scenarios B and C are respectively savings. -20 and 11 mPE / tonne waste brick. In all three scenarios, there is some consumption of diesel for transport, as for the sorting, which is higher in B and C (Miljøstyrelsens 2013).

When comparing, the potential environmental impacts for scenario, the ranks are made within individual impact categories. As seen in Figure 30, and as already mentioned, it was only possible to rank the scenarios in four out of twelve impact categories since for the rest the level of uncertainty was too high, or the valour of naturalisation was too small to be taken in consideration. In these categories the results were relatively clear, showing that scenario B (bricks reused in facades) have less impact on the environment for all four categories. Scenario C (bricks treated to be used in contexts not exposed to weather) it classified as second in three categories but was at the end of the fourth category since it resulted to emit the highest photochemical ozone formation (Miljøstyrelsens 2013).

Transport Processes contributed both with environmental savings and loads. The downcycling of bricks contributed on environmental impacts mainly because of leakage of heavy metals (Cr (VI) and Pb) (Miljøstyrelsens 2013). Consumption of natural gas and the accompanying emissions of fossil CO_2 by firing bricks plays a predominant role during the production of new bricks. In conclusion, when the environmental impact categories here greenhouse effect, acidification, photochemical ozone formation and consumption of fossil fuels, are taken in consideration, it results that in general, the reuse of bricks has less impact on the environment than the downcycling process (Miljøstyrelsens 2013).

Miljøpåvirkningskategorier		**Genanvendelse (scenarie A)**	**Genbrug med substitution af facadesten (scenarie B)**	**Genbrug med substitution af bagsten (scenarie C)**
Ikke-toksiske påvirkningskategorier	Drivhuseffekt	3	1	2
	Stratosfærisk ozonnedbrydning	-	-	-
	Fotokemisk ozondannelse	2	1	3
	Forsuring	3	1	2
	Terrestrisk eutrofiering	-	-	-
	Ferskvandseutrofiering	-	-	-
Toksiske påvirkningskategorier	Humantoksicitet, cancereffekter	-	-	-
	Humantoksicitet, ikke-cancereffekter	-	-	-
	Økotoksicitet	-	-	-
	Partikler	-	-	-
Forbrug af abiotiske ressourcer	Grundstoffer	-	-	-
	Fossile brændsler	3	1	2

Figure 30 RANKING THE SCENARIOS. "1" IS THE BEST AND REFERRING THE LARGEST ENVIRONMENTAL SAVINGS OR MINIMUM ENVIRONMENTAL IMPACT. "-" REFERRING TO THE SCENARIOS cannot be ranked (Miljøstyrelsens 2013).

5.1. Conclusions

It is important to emphasize that environmental assessment results are based on numerous assumptions, such as the percentage of the quantity of bricks that can be reused and recycled after the different processes, and that the bricks treated for the reuse completely replace new bricks, therefore no bricks are been manufactured. Overall, it can be concluded that reprocessing brick waste for reuse gives several environmental savings if compared to crushing them. This is mainly because replacing new bricks with the old ones, avoid the environmental costs of manufacture of bricks, including energy consumption and associated emissions and the extraction of raw material. In the four environmental impact categories greenhouse effect, acidification, photochemical ozone formation and resource consumption in the form of fossil fuels, where the scenarios could be ranked, it results that the scenario in which bricks are reused in facades is the one that leads to greatest environmental savings in all categories. Reusing old bricks for internal purposes also showed greater potential environmental savings than downcycling in three categories. Scenario B avoid more environmental impacts since the production of new bricks that are not exposed at weather uses less energy when produced, therefore when the scenario C is compared to the one that produce them, it results that the difference between the two scenarios in terms of energy is less if compared the scenario B with the once that studies the production of bricks to be exposed at weather, which requires high quantity of energy. This is the reason why the bricks exposed to weather gets the first place for the 4 environment impact categories. On overall, replacing new bricks with old ones, would avoid the environmental impacts given by the production process itself, including energy consumption and associated emissions. In facts, Energy consumption and emissions coming from the reuse of bricks is less if compared to the production of them (Miljøstyrelsens 2013).

Additionally, Gamle Mursten calculated that the improvement of the reuse of bricks could lead to the creation of about 400 new jobs (European Commission 2020).

6. What issues do stakeholders face at each phase of the life cycle of bricks?

At this point is known how bricks are produced, downcycled and prepared to be reused and it is also clear how the three processes affect differently the environment. With this section the writer wants to provide information regarding the problems that the stockholders face across the different phases of the bricks life cycle which drive them to downcycle the material instead of preparing them for their reuse and why new bricks are chosen over the used ones. The reported uses a document provided by Niras in 2015 which was redacted after interviewing different stakeholders involved in the different life cycle phases of the bricks.

6.1. Problems faced by stakeholders in each phase of the bricks' life

6.1.1.Design

In a traditional building case is typically the architect who proposes the use of bricks therefore is the architect that decides along with the owner of the building if to use new or old bricks. Consultant can be considerate during this phase and the contractor is the last figure to be taken in consideration. The decision of using new or old bricks is based on appearance, price, and possibilities. On the other hand, in turnkey competitions, it is often the contractor who invites architect and other consultants to design and price a building according to a given program (Niras 2015).

To get to know which are the problems that push not to prepare bricks for their reuse, Niras interviewed three builders, two architects, four contractors, and Kalk- og Teglværksforeningen. Based on the opinions of the interviewed respondents, the barriers related to the improvement of the reuse of bricks in this phase are connected to the process, quality and technical characteristics of the stones as well the economy aspect and lack of knowledge and experience (Niras 2015).

The infrastructures are designed to have a specific look, in this sense designers are not sure that the quantity of used bricks can allow to achieve the aesthetic pattern desired, so the delivery security influence the decision. The construction of a building can become very expensive if the building materials cannot be delivered in the right amount and quality at the right time. This is a problem that builders, consultants and contractors point to. More respondents expect the security of delivery to become a minor element of uncertainty as the market develops and larger quantities of reprocessed bricks are available. Delivery security is a greater challenge for large buildings than for smaller, because the bricks used come from different demolition sites, this means that it will be a challenge to ensure that the stones have the desired characteristics. Additionally, most of the responders believe that the bricks lose their characteristics such as their strength and their resistance to salt and froze once they are taken out from the original structure since they undergo to a lot of stress (Niras 2015).

The price of reused bricks plays a significant role for the builder and contractors in selecting the right brick for the building. Several respondents point out that it is slightly more expensive to use reprocessed bricks than the new ones. Svend Roed Larsen who works as consultant for Randers Tagle explained that the production of new bricks is cheaper since it involves less transportation and the need of less workers which is also one of the reasons that push companies to produce new bricks instead of taking up the reprocessing business (Larsen 2020). Whether the price will be decisive depends on the deals between the stakeholders, and on the overall financial framework of the project (Niras 2015).

It has also been found out that there is not so much information about the characteristics of reused bricks in the market which makes the stakeholders unaware of the different options available. In construction, it is widely used that consultants and contractors rely on sources such as SBI anvisninger, BYG-ERFA magazines and publications from the industry information council (in this case Murerfagets Oplysningsråd MURO). Having access to a recognized source is not only essential for the drawing part, but it also influences financial decisions. Stakeholder groups pointed out that it would be helpful if technical and aesthetical information regarding reprocessed bricks was made available through one of these recognized sources (Niras 2015). This last issue it has partially been solved since Gamle Mursten had been taken in consideration for prices by the EU for its unique sustainable technology which guarantee a CE certification to their final product, so the product is listed in some of these sources (Gamle Mursten s.d.). Besides that, the problem of knowledge remains since the stakeholders can just be not interested in exploring new possibilities and so does not research the topic.

6.1.2.Construction Process

The construction process is the actual execution of the building. The decision regarding this phase are taken before the physical construction starts but during the same process changes can occur. The materials must arrive at the construction site at the right time and must be the right quality. As explained above, delays can have a domino effect and affect the entire rest of the project - perhaps even with greater delays than the original one and this is not positive since the use of labour and machinery is tightly planned. Several different professional groups are involved in this phase, and they are: Architects, builders, and contractors (Niras 2015).

They agreed with the fact that the process used for building up the infrastructure and the budget available can influence the decision of using old bricks. Everything is connected to the delivery security of the material as for the design phase. The reused bricks can have faults (as new one) which can create delays and so more expenses for the stakeholders. The difference lays on the fact that new bricks with the same characteristic are always available in big quantity so if one brick is damaged during the construction process, it can be easily be replaced while reprocessed bricks are limited in quantity so it is more difficult to find one more bricks with the same characteristics to replace the hypothetical broken brick. This is the same reason that push the constructors to manage the bricks more carefully when installing them and so more time is used to produce the costruction (Niras 2015).

In the case of larger construction, the reused bricks used will come from several different demolitions, so it is essential to make sure that the stones are mixed continuously to ensure the aesthetical expression sought (this affect also the decision makers working on the design phase). In cases where stones come from several demolitions, it can be a problem to determine whether the delivered stones are within the agreed characteristics and verify so requires time. Furthermore, the bricks do not always meet the standard dimensions of bricks needed for the construction. If the wall dimensions are to be observed and the bricks have not the right dimension it is necessary to vary the thickness of joints which affect the economy of the project and the time to finish the realisation of the final product. (Niras 2015).

6.1.3. Demolition

The developer or building owner has the responsibility to perform an environmental screening to assess if content of hazardous substances are present in the building, at the same time the expert can verify if the construction products and materials present in the building are reusable. If the material wants to be reused, a selective demolition is a must since it gives the possibility to maintain construction fractions intact. The stakeholders before proceeding with a selective demolition must take in consideration if it is more profitable to hand the stone to be reprocess or to downcycle them since the first option is more time-consuming (Niras 2015).

Five different demolition companies where interviewed around Denmark and all of them agreed that there are 5 different subcategories in the demolition phase that influence the possibility to choose either to send bricks to be prepared for their reuse on to be downcycled along with the process to follow for the demolition itself, they are: the logistic, the time available to do the demolition, the economy aspect, the knowledge and experience of workers involved in this phase (Niras 2015).

A selective demolition requires the involvement of more skilled workers who are usually more expensive than the regular ones and it also requires longer time if compared to a regular demolition and more space on site since the material has to be sorted on site. It is also not easy to find skilled workers since there is a lack of knowledge regarding selective demolition. The extension of time is not always possible as the demolition must be completed within a tight time frame, so it is not possible to spend more time in a gentle demolition and sorting (Niras 2015).

Logistic is considered the key barrier in this phase to increase the rate of the reused bricks. Two types of logistic challenges are found in the demolition phase: not enough space in the demolition site which is needed to sort the materials and long transport distances between the site and the factory that prepare bricks to be reused. Sometimes demolition sites due to their size do not allow to sort out the material derived by the demolition and for the specific case of bricks this lack of space does not allow to sort out bricks from other fraction materials, which is a requirement if they are sent to the factory to be prepared for their reuse. The factory will not sort bricks from other material (such as iron or wood). Logistical challenges associated with transport are related to the distance between the demolition site and the factory, as well as the amount of bricks to be transported. Most of the demolishers interviewed gives their bricks to the company Gamle Mursten which has its facilities in Svendborg, and recently a new facility in 2018 opened up in Brønderslev in collaboration with AVV, so for North Jutland this is quite market in expansion. It means that it is not economic for them to hand over the bricks if the demolition takes place far away from the factories, as transport costs is usually covered by the same stakeholders that manage the demolition and greater is the distance greater is the transport cost. Whereas crushing of bricks is being driven by different actors across the country and therefor transport bricks for this practice is cheaper.

Several demolitionists emphasize that the choice between the reprocessing of bricks and their crushing is solely based on economic considerations. The economic barriers are to a large extent linked to the above barriers, which in turn are closely related to the income that the stakeholders can have when handing over the bricks to be reprocessed. If the bricks sent have a low quality, Gamle Mursten requires a payment in order to take them in, instead if the material has a high quality, the company pays 0.5 DKK for each brick sent (Niras 2015)

6.1.4.Barriers in the reprocessing phase

When bricks are taken from a demolition site, they can be reprocessed to be stored in a warehouse divided by size, colour and quality, or they can be used in the same structure if it is being restructured, or in the best case, they have been already bought to be used in a new construction. The stakeholders involved in this phase are the companies that reprocess the bricks like Gamle Mursten, but their ability of reprocessing the material depend on the stakeholders that work in the above-mentioned phases. In facts, the amounts of bricks reusable arriving to the reprocessing factory, depends on the technique used to demolish the structure, the material used to line up the bricks, by the design of the construction (if it is modular or not) and by the knowledge of the different stakeholders involved during the life cycle of the bricks. In general, it can be difficult for the factories that reprocess bricks to provide the right amount and quality of bricks to the client since the demolition companies prefer to crush the bricks than send them to be prepared for their reuse for the reasons explained above and therefore there is not a physical capital to work with. Additionally, the demolition can be made so badly that the bricks will arrive to the factory too damaged, so they can not be reprocessed. The demolition could be improved if the building is designed to be modular, and therefore pieces of it could be easily removed without being damaged and could be reprocessed. The luck of knowledge of the stakeholders involved in above-mentioned-phases does not help the purpose of reusing the bricks and therefore it makes impossible to achieve a circular system. Additionally, there is a misconception that belongs to stakeholders that reused bricks can be used only for decoration and cannot have structural functions, which is not true. It has largely been proved that the bricks once properly reprocessed conserve their characteristics. The limited knowledge of used bricks given by the stakeholders involved in other phases, is the biggest barrier since cause the lack of bricks to reprocess (Niras 2015).

Additionally nowadays bricks are lined with the use of cement, a technical approach that do not allow companies like Gamle Mursten to clean the bricks to be reused, since the cement is stronger than clay and during the process of cleaning, the brick broke before the cement. If this market wants to be expanded this technique must be changed (Niras 2015).

In 2018, a partnership between AVV (a waste management company) and Gamle Mursten gave born to a new company called "Gamle Mursten Nord" which does not depend on Gamle Mursten and it does not depend on the last-mentioned company. Differently from the mother company, it does not buy the bricks but instead it takes care of the transport of the material from the demolition site to the factory in Brønderslev. Kurt Brandi the head of direction of AVV- Gamle Mursten Nord, stated that since the stakeholders are not paying for the transport, do not put a lot of effort on sorting the material before sending it to them, so the truck arrives to the factory full of bricks along with other fraction materials. This forces Gamle Mursten Nord to sort the different material in the factory which makes them lose time and reduce the number of bricks cleaned at the end of the day (Brandi 2020).

Nowadays the reuse of old bricks is a lunched market in the south and central Denmark, so it is easier for Gamle Mursten to get in touch with the stakeholders involved in the bricks value chain and therefore create for itself a capital material to work with. In North Jutland, the reuse of bricks is quite a new market and so stakeholders are interested on the topic, but at the end they always prefer to use new bricks and to downcycle them since they still have an old business-mind-set (Brandi 2020). The three professionals interviewed by the reporter, Svend Roed Larse, Claus Juul Nielsen and Kurt Brand agreed on the fact that there is a lack in policies, which drives stakeholders to use new bricks and to downcycle them.

6.2. Conclusion

In 2015 Niras held different interviews with several stakeholders involved in the phase of design, construction process, demolition process and the reprocessing phase of bricks. For each phase was found out that the main problems that drive stakeholders to downcycle the bricks and use new bricks are connected to the economic and time restrictions. Not all bricks that arrives to the reprocessing factory can be prepared to be reused since some of them had been damaged during the demolition phase. To have more bricks reusable it is needed a selective demolition which requires skilled labours and more time if compared to a regular demolition, two factors that lead to more expenses for the stakeholders involved in the demolition phase. The luck of knowledge about the product and systems available to prepare bricks for their reuse, it makes impossible for companies like Gamle Mursten that prepare bricks for their reuse, to have a physical capital to work with and it directly affect the quantity of old bricks available in the market and so it makes difficult to have products to present to stakeholders that are involved in the design phase which are concerned along with the stakeholders involved in the constructions phase about delays that could occur if the right quantity and quality of bricks are not available at the right time, which will lead once again to more expenses for the stakeholders. One mor problem is given by the fact that nowadays bricks are lined up with the use of cement, which is a stronger material than the brick itself, so during the process of cleaning the bricks brake before the cement and is not reusable. Unfortunately, there is no such technology that can solve this specific problem. With this sub question it has been showed how the different stakeholders in different phases can influence the different outcomes across different phases especially the reprocessing phase. It has been cleared how the success of prepare bricks for reuse starts since the design phase, in fact if a structure would be designed in a modular way, the selective demolition would be easier and more bricks could be collected without being damaged and so the number of reusable bricks in the market would increase and there would be not big concerns regarding the delivery of the product.

7. Which solution seems to be the most appropriate to unfold the reuse of bricks?

639 000 m3 of clay was extracted in 2018 in Denmark, of which 139 000 m3 came from North Jutland. This quantity increases of about 147 000 m3 across the country and about 56 000 m3 in North Jutland. This data proves that Denmark is not looking at waste as resource, since in general the extraction of raw material is increasing and therefore new products are realized. Specifically in the bricks market, is calculate that about 47.3 millions of bricks could be reused, instead only 3 millions of bricks is being reintroduced into the economy cycle, in facts, bricks in Denmark are mainly downcycled since this approach is cheaper and faster (Miljøstyrelsen 2017). This solution is considered the second worst approach in terms of sustainability by the waste hierarchy and the last solution to be used by the definition of circular economy provided by EMF. The report helped to understand who are the stakeholders involved in the bricks market and so who is responsible for the success of reaching a circular system and how having them working together could change the current system. They are whoever works with the extraction of raw material, the manufactory of bricks, their transport across the different phases, who takes care of selling them, who use them to build constructions, along with who takes cares of the demolitions and the waste management. It has been showed how the processes of manufactory, downcycle and the preparation of bricks for the reuse happen and what are the characteristics that bricks must conserve over time if it wants to be reused. Through the use of an LCA commissioned by the ETA, it has been proved that the reuse of old bricks has less impacts on the environment and the expansion of the reuse market would create about 400 new job positions (Gamle Mursten s.d.) impacting positively the social dimension and therefore the economy one. Different problems are faced by stakeholders across different phases and they are the reason that lead them to use new bricks and downcycle them. They are connected to the economic framework, to time restriction, to the availability of the product in the market and to the general lack of knowledge that regards the reprocessed bricks. The report with this sub question decides to suggest a solution that could improve the reprocessing phase focusing on North Jutland since is a developing market in the region. Additionally, is proposed a solution that can help the stakeholders involved in the design phase to choose used bricks and some brief recommendation for the construction and demolition phases are given to solve the-above-listed problems. These solutions aims to help to achieve a circular economy system following the practices suggested by EMF and to step up on the waste hierarchy to impact as less as possible the environment and to create a positive impact on the social dimension through the creation of new jobs and therefore on the economy dimension.

7.1. North Jutland

Northern Jutland is an undergoing a positive developing region in north Denmark and is composed by 11 municipalities and has 590,000 inhabitants. It is considered to be the hub that connect Denmark with the rest of North Europe thanks to Aalborg airport and the Frederician Port (Region NordJylland 2019).

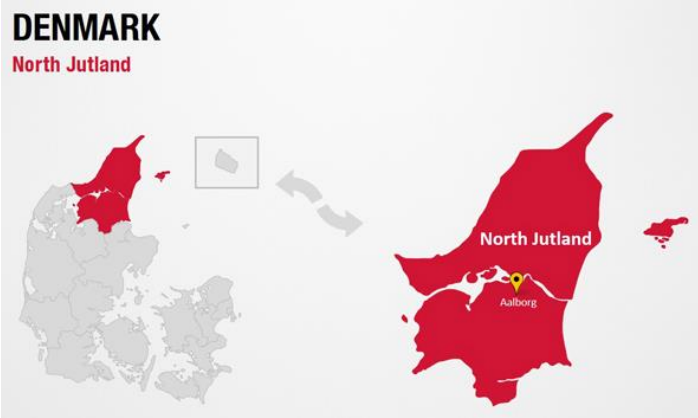

Figure 31 North Jutland (Region NordJylland 2019)

The North Jutland business structure differs slightly from the rest of the country. There are a relatively large number of small and medium-sized companies and very large ones, while traditional industries, such as agriculture, industry, and construction, are slightly over-represented as for private industries. In 2019 the region has adopted a Regional Development Strategy (RUS) that want to obtain a continuous, a competent and attractive North Jutland. The core initiatives are identified through dialogue with stakeholders and are the following: establishment of a 3rd Limfjord connection, optimization the regional train operation, improve the use of technology across the region, strengthening educational opportunities and skills development in all parts of North Jutland, the creation of circular economy system within a strategic energy plan (Region NordJylland 2019).

The goal is to achieve a sustainable development, to have a coherence and balance across the region, to allow the region to gain opportunities of globalization and to keep an open mind in terms of cooperation being innovative. In 2015 it was created a business collaboration among the municipalities in North Jutland which goes by the name "Business Region North Denmark" (BRN) and a platform where the northern Jutland municipalities and the one belonging to the Northern Jutland can communicate and cooperate on common interests and joint initiatives, which are considered to be important to strength the growth of the region. The goal is to identify the right agenda for the region, to initiate the proposals launched by stakeholders, to coordinate strategies and activities and allocate funds for new strategies across the region so to unite the region and have a homogenised development (BRN s.d.).

The research question used in this report make use of all the strategies adopted by the RUS, excluding the approach of globalisation. The development must produce lasting results, and the efforts must be initiated on an economically and environmentally sustainable and evidence-based basis. At the same time, efforts must be socially sustainable and thus create equal opportunities for all parts of the region. The principle of cooperation aims to create strong strategic collaborations and partnerships among the different stakeholders across the region to reach great results and goes along with the innovation principle which wants to use the available technology at its best. The coherence wants to achieve a great mobility connection across the region for passengers and freight, meanwhile the globalization principle aims to create an international economy for the region (Region NordJylland 2019).

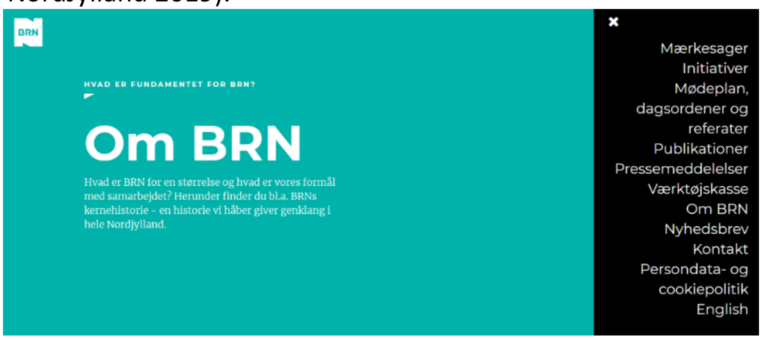

Figure 32 Façade of the Web page BRN (BRN s.d.)

Figure 33 The 4 focuses of BRN (BRN s.d.).

Under the section "Business Development and Job Creation" on the BRN platform, there is a project that works with achieving a circular economy system in the region and is called "Circular Northern Jutland". This is to ensure that the economic and job benefits of the initiatives are rooted in the region's business community to the greatest extent possible and it wants to achieve a sustainable development having the three dimensions (social, environment, and economy) working together (BRN s.d.).

An example of this purpose is given by the partnership created between Brønderslev and Hjørring municipalities which gave born to a waste management company called Affaldsselskabet Vendsyssel Vest I/S (AVV). The company's purpose is to plan, establish and operate the necessary plants for handling, processing, recycling, incinerate and dispose waste for the municipalities and to achieve a cooperation across North Jutland through research and the development of new ideas. The board consists of five council members once for each municipality that works with AVV, whose term follows the municipal elections. The current board of directors is elected for the period 2018-2021. Once for year this board gather to have a look at the goals achieved and create new plans to improve the waste management across the region (AVV 2012).

7.2. A technology solution for the reprocessing phase

AVV manage different types of waste and in 2018 decided to open a factory in Brønderslev that deals with the recovery of old bricks, which it has been mentioned in sub question three and it was called "Gamle Mursten Nord". This same factory was open and directed with the help of Gamle Mursten using the same technology that guarantee a CE certification for the bricks reprocessed. On the 1st of May 2020 AVV-Gamle Mursten Nord was incorporated by "Cirkulær Nord Fonden" so changes in the organization might happen (Brandi 2020).

Gamle Mursten Nord works slightly different from the mother company. As already explained, it does not buy the bricks but instead pays and organize the transport of the bricks from the demolition site to the factory in Brønderslev. This somehow, push the stakeholders that own the bricks to lean towards sending the bricks to be reprocessed since they will not spend money on the transport of the waste and it makes them to save the money that would be used by them to send the same bricks to be downcycled. Before sending the bricks to Brønderslev the owner of the bricks is called to sort out the material since Gamle Mursten Nord asks to receive bricks separated from other fraction material. Unfortunately, as the owner of the bricks is not paying for their transport, he does not put much effort on sorting the bricks, so the factory often receives bricks that are not reusable or attached to other fraction material. This forces Gamle Mursten Nord to sort the material in the factory, making them lose time reducing therefore the quantity of bricks cleaned for day. If the material would arrive properly sorted, the factory would be able to reprocess a bigger quantity of bricks (Brandi 2020).

During the past years, Gamle Mursten with the help of EPA and different engineer companies, have been working on developing a new technology to push stakeholders to use old bricks and improve the circularity of the current system. They came up with the creation of a coarse sorting plant which is able to separate the different material by diameter, so that only the bricks suitable for reprocessing would be transported to the factory and it would leave the no-reusable material at the demolition site. The biggest challenge was to develop the right modular sieve to sort the bricks and so to decide what was the right size to sort. At the end it was decided to allow the sorting of "half bricks" since as explained in sub question one, Gamle Mursten cut the bricks along the thickness to be readopted in the modular block-wall system or to customize them if requested. The machine can sort better small blocks instead of big ones since it is able to separate small fraction materials from the bricks through the vibration provoked by the belt that transport the material along the machine but it is not able to "brake" blocks. It was also tested how the bricks would react to the vibration to see if they would be damaged by the vibration and it was discovered that this vibration helped the purpose of separating the mortar from the bricks. This is especially helpful during the winter season because the moist of mortar can cause a reduction in production efficiency as it becomes greasy and settles along the brick and must be peeled away by hand. If the mortar is effectively sorted before the bricks arrive in the cleaning plant, less stops to clean the mortar will be needed and therefore more bricks will be reprocessed. This was a derived positive effect that the project had not foreseen or sought (Miljøstyrelsen 2019).

The technology development resulted in a mobile coarse sorting plant with a capacity of 50-100 tonnes of construction waste per hour. The existing Portafill that sorts concrete and soil was used as base and it was revisited and studied to be adapted to sort bricks. The problems pointed out by the stakeholders involved in the demolition phase during the investigation that Niras held in 2015 and mentioned in sub question three, such as lack of space and mobility on site, were taken in consideration while developing the sorting machine. Readapting a conventional mobile coarse sorting plant needed a shorter development process as only few parts needed to be optimized and developed for the purpose sought. The development of a new technology would have required more time to be developed and the more economy investments. The machine is more compact than a regular Portafill, it has a dimension of 10.5x2x3 meter when is opened and it can be folded and transported were needed by trucks thanks to its practical design (Miljøstyrelsen 2019).

Figure 34 Sorting mobile machine (Miljøstyrelsen 2019)

Even if its size is compacted, it is still able to sort large quantity of bricks and it can be used in small demolitions sites. Additionally, it has caterpillars tracks which allows the machine to move better on the site, and it can be controlled remotely. Another advantage of using a conventional plant is that it is a known technology so the demolition companies may already have worked with similar machines in the past for sorting soil and concrete and this means that is required minimal guidance to operate the system on site (Miljøstyrelsen 2019).

The machine is able to reach high quality standards in regards of sorting which would create an economy advantage for Gamle Mursten Nords, since less bricks not treatable would be transported to the factory and so extra expenses are avoided for the transport and the bricks can be treated straight away as they arrive and therefore at the end of the day, more bricks would be reprocessed (Miljøstyrelsen 2019).

The new technology has three stack conveyors, which allows the sorting of waste into three different fractions: whole and half bricks (shipped to be prepared for the reuse), larger tiles that cannot be separated and mortar sand in different grain size which can both be used as a running surface or filling of basement decks (Miljøstyrelsen 2019).

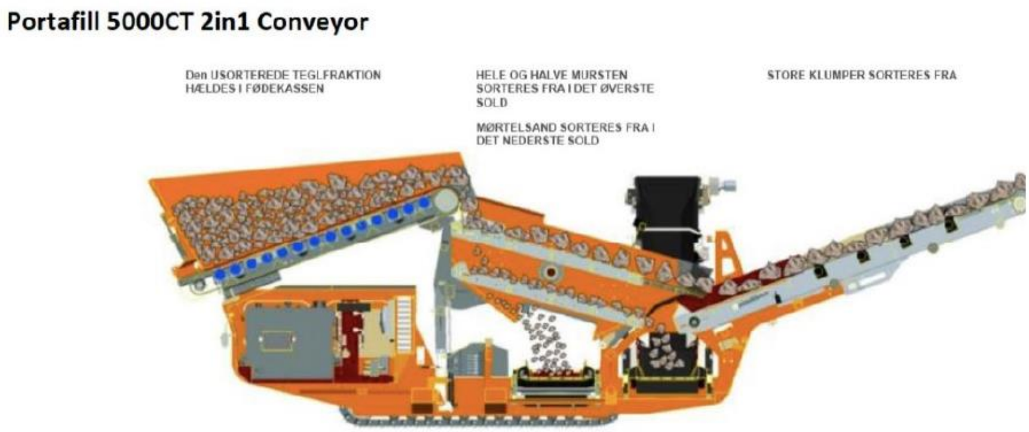

Figure 35 Mobile sorting Machine (Miljøstyrelsen 2019)

It is both the distance between the "teeth" on the soldier and the inclination of the teeth that have been crucial to the development and to achieve good results. The machine can do the three sorting since it has three different grids. The waste construction is poured into a bottleneck and it is transported thanks to the belts over the grids. The lower one ensures that the mortar sand is separated from the rest and does not allow the passage of material that has a diameter that is bigger than 4 mm, the second capture material with a diameter between 4 and 60 mm and the last one sorts material with a diameter between 60 and 800 mm such as the half bricks and bricks. The grids can be replaced on the base of what the stakeholder desires to sort. It is suggested to run the machine on a law speed if a high-quality sorting is sought (Miljøstyrelsen 2019).

Figure 36 Biggest grid that separates bricks from another fraction material (Miljøstyrelsen 2019)

Figure 37 Mobile sorting machine in action (Miljøstyrelsen 2019)

Figure 38 Mobile sorting machine (Miljøstyrelsen 2019)

The machine belongs to Gamle Mursten and can be rented through an agreement with them, they charge between 4 to 8 euros por each ton of material sorted, and it has a noise around 100db if a person stands nearby the machine (Nielsen 2020) which is the same noise that a mp3 generates playing at full volume or a car horns. It is considered to have a degree called “very loud” over a scale that goes from “fainting “(up to 20 db) to “painful and dangerous”(between 130 and 140 db) (American Accademy of Audiology 2010) but The Danish Working Environment Authority’s Noise Order states that whoever is working in environments with a noise level over 85db must wear protection since long exposition to higher level of noise can create permanent damages to the hearing (Arbejdsmiloweb.dk s.d.). The sound drops as the person moves away from the source, usually if you are 100 mt away decrease to half (Measuring and Calculating Sound Levels s.d.). So, at 100 mt far away from the machine, people will hear 50 db which is as loud as the sound of a rainy moderate day. The dropping of noise in distance varies on the base of wind and condition of the environment in which the sound is being released (American Accademy of Audiology 2010). Taking in consideration the data regarding the noise just provided, the writer believes that the noise is not a problem if the machine is used in residential area, and Gumle Mursten did not express any concerns on this regard. Nielsen explained that the machine can be easily used in residential area, since to start work constructions, it is needed a temporary permission that allows to make noise in certain hours and therefore the machine can be used (Nielsen 2020).

When studying this new technology Gamle Mursten and ETA started talking to different municipalities to understand if themselves would be open to the idea of using them as solution to help the purpose of sorting more bricks and the answer was positive. The North Jutland region was excluded by this research, since in this region they focused on creating the partnership that gave born to Gamle Mursten North (Miljøstyrelsen 2019).

Claus Juul Nielsen states that the machine works perfectly and so far, it has no created any problems and it has been successfully used in the smallest demolition sites. Right now, there is only one machine in stock, and it is in Skotlandsvej (Nielsen 2020). Since Gamle Mursten owns the machine it should be easy to give the permission to reproduce the same machine to be used by Gamle Mursten Nords. The reporter suggests that once the machine is in possession of Gamle Mursten Nord, the same company should make the machine available for the stakeholders to help the to sort the bricks in North Jutland and therefore to increase the material capital to work with for Gamle Mursten Nord. It could be given for free if the stakeholders would pay its transport, instead of paying the transport of bricks towards the downcycle site. Since the machine can be used to sort different material, it can be rented (under payment) by the same stakeholders to sort other materials after sorting the bricks so Gamle Mursten Nord would have an extra income.

The writer believes that this is the best practical solution to use, since it is an existing technology that can be easily replicated and used right away in a short term, and it is accessible and available for everybody.

Additionally, it is able to solve different problems for the demolition and for the reprocessing phases. It should also be possible to have more knowledge about this machine, since it is quite hard to find information about it and it is possible to get to know about this machine only throughout Gamle Mursten which does not help the purpose of its spread. More advertisement should be created for it.

Gamle Mursten Nord should also start expanding its market, since it only sorts whole bricks, and so should follows the practice use by Gamle Mursten which sort "half bricks" and customize them to raise the rate of bricks reusable, as explained in sub question one. This solution works only if stakeholders involved in both phases, demolition, and reprocessing are willing to work together and reach an agreement for the use, the transport of the machine and the expenses that concerns it.

7.3. Collaboration over the horizontal level

This solution is led by one of the principles followed by the Regional strategy plan of having stakeholders working together to enhance the reuse of old bricks. Doing so is not easy, since they are driven by the economic dimension and as long as they are not thinking that including the ecological and the social dimensions can bring an income, it will be hard to shift their mind into a circular system (Emerald Group Publishing Limited 2014). As showed in sub question two, the practice of reusing the bricks would lead to free the environment from several burden, since the extraction of raw material and different type of emission will be diminished. Additionally, the economy sector would improve, since through the right collaboration all the stakeholders will have an income and no business involved in the value chain of the preparation of the reuse of bricks would be left aside and the creation of new jobs would be possible (World Wildlife Fund 2000).

The reporter suggests an improvement on horizontal collaboration which as mentioned, identifies groups of stakeholders using different strategies to achieve the same goal. It is usually underestimated since the goals of stakeholders are more individual (Emerald Group Publishing Limited 2014). Focusing on the horizontal aspect is possible to create a synergy among stakeholders with different needs in different phases but with same goal improving the decision making. To create this synergy, different factors must be taken is consideration. Stakeholders must be aware of the possibilities that the market is offering in terms of possibilities for the use of the waste as resource and the technologies available to achieve a circular economy system in the market. Adopting a new system using the old tools such as the use of water or chemical products to clean the bricks it might help to obtain a circular system, but it would not be completely sustainable since there would be a waste of water and chemical product that at some point has to be disposed and therefore an extra irreversible impact on the environment will be produced. To achieve a high degree of sustainability is essential to use the right tools in the right context (Emerald Group Publishing Limited 2014).

The writer suggests using the already existing platform BRN to improve the communication among the stakeholders so there is no need to invest on a new technology, but just the need of updating the already existing one which would save money. As mentioned above, BRN is a platform created to allow stakeholders in North Jutland to communicate and cooperate across different business, levels, and municipalities (BRN s.d.).

Figure 39 Information provided by AVV- Gamle Mursten Nord (AVV s.d.)

To push the stakeholders to use reprocessed bricks, especially the one involved in the design phase, it is essential to provide them information about the products. The writer believes that currently Gamle Murstern Nord, which uses AVV'S website to provide information about the products, is not well developed. Figueres 39 shows how the information regarding the bricks are provided which is clearly not enough for a designer to think of use the product in new constructions since patterns are usually created.

The writer suggests a creation of a database in the section of the circular economy of the BRN website, where it is possible to catalogue the different waste construction reprocessed and each material should have its section. Whenever a demolition is taking place, the owner of the bricks should upload the information regarding them on the same platform. The reprocessing phase would be held by Gamle Mursten Nord, but in this case, the same stakeholders could directly sell the bricks instead of giving them up and pay a percentage of the selling to Gamle Murstern Nord for their service. In the section created in BRN (the writer provide an example in figure 42 how it should look like), it should be indicated what are the products available, with a picture of how they were when arrived at the factory and how they become once cleaned. This would help the stakeholders to see the physical difference between "before" and "after". Of course this should not been done for each single bricks that arrive from a demolition site, but only for one that would represents the rest of the bricks that are coming from the same construction site. It should be reported their material passport which will talk about their provenience, they role in the old infrastructure, and if it possible the origin of the raw material and the process of production. Additionally, it is needed the different physical characteristic such as salt and water resistance and which role they can cover, and the availability in the stocks in terms of numbers.

<table>
<tr><td>Before</td><td>After</td></tr>
<tr><td>
Figure 40 Used Bricks on a demolition site (Alamy s.d.)</td><td>
Figure 41 Used Brick Reprocessed (Single Brick Isolated s.d.)</td></tr>
<tr><td colspan="2">Provenience: Aalborg, Boulevarde 5
Use: used for internal purpose
Raw material : Aalborg, extracted in 1920
Size : 54x108x200
Resistences: (Salt, durability etc)
CE certificatio : ----
Texture : Smooth red
How can be used : structural, esternal and internal roles
Quantity available : 17000 pieces</td></tr>
</table>

Figure 42 Suggestion of how it should look the profile of the bricks of the BRN platform

Doing so whoever is working on a new project would see visualized the different information about the bricks recovered and would be easier for them to buy bricks for their future needs. Visualizing the product and quantify it would help the designer to create an aesthetic sense with the specific bricks available and adapt the new construction to what the market offers (Niras 2015).

The main goal is to match bricks coming from a demolition site with a new construction to close the loop, this would reduce the doubts that stakeholders have regarding the availability of the bricks for their specific infrastructures and their aesthetic goals. This approach would close the loop and guarantee the use of recovered bricks guaranteeing positively impacts on economy, environment, and social dimensions (Den Sociale Kapitalfond Management ApS 2018).

7.4. Recommendation

In sub question three was highlighted how each stakeholder has different problems in each life phase of the bricks. This section provides brief recommendation that would help to solve the problems not touched by the above-suggested-solution. It is important to remember that to reach a well-working-circular economy system, is essential that each single problem is taken care as much as possible and that the different stakeholders work together on horizontal and vertical levels.

7.4.1.Construction Process

In the construction process was identified that the problems are mainly related to the process itself, a lack of knowledge given by the stakeholders and problems with the economy aspect.

Problems in Construction Process	Recommendation
Process	• Do not use cement to stick bricks • Be more flexible about the use of different bricks in the same construction (colours, size etc)
Knowledge and experience	• Make aware the builders of the possible material available on the market that can be reused and not, and give them information about the used material available in stock. Gamle Mursten Nord should be more open to show their products and the related information to the public (as already mentioned) • Give to stakeholders classes about the difference in using reprocessed and new bricks in the construction process, which would include the technical aspects and the impacts that the production and downcycle processes have on the three dimensions and compare them to the ones given by the use of reprocessed bricks • Have a concrete guideline to understand how to manage old bricks during the construction, so no to damage them
Economy	• For public projects, the municipalities should choose to work with construction companies that use recovered material • The state should charge less for the different permissions when the material is being taken by an old structure and reused in the new one

7.4.2.Demolition

To reprocess as many bricks as possible in good shapes, is essential to proceed with a selected demolition, which is a complex process that costs time and therefore affect the budget of the company. Additionally, there are not so many skilled workers that would be able or available to work in each demolition.

Problem in the Demolition Phase	Recommendation
Process	• The use of machine to sort on site only the reusable bricks to be sent to the factory to be cleaned

	• If the site is small, try to extend the site
Time	• It should be given the possibility to extend the time frame of the demolition if the company decides to use the selective technique and the company should not be fined since it was chosen to proceed with a sustainable approach • Improving the communication between collaboration between demolish companies, municipalities and factories that recover bricks
Economy	• Municipalities should subsidy to the stockholders involved in the process of demolition that decide to go for a selective demolition, which could be the assignment of works needed in the public sector to them • The policies regarding demolitions should be revisited in terms of fines, time, and costs. If a sustainable approach is taken, the company should be helped under these aspects
Knowledge and experience	• Giving to demolition companies' employees free education about how to do a selective demolition • Workshop for the demolition companies to inform them about the possibilities that they have through giving away the material

In 2018 the Nordic Council of Ministers released a report regarding the concept of Circular economy and how it is understood in The Nordic countries. In Denmark stockholders, that work in the construction industry, thinks that the value chain would improve its efficiency if the policy makers would focus on providing more regulations for the phase of design, refurbishment of the product and on making policy to improve the reuse or recycling of the waste coming from a construction site. "The underlying assumption is that the building owner and developers who finance the building set the criteria for the design and demolition of buildings. They hereby have a key role in initiating a transition toward a more circular economy in the building and construction sector" (Ministers 2018). This statement was backed up by Svend Roed Larse, Claus Juul Nielsen and Kurt Brandi since the current policy do not support the practice of reuse. It looks like producing new bricks and downcycle them cost less than reprocessing mainly because the current energy tax profile. The energy tax in Denmark are created in regards of the EU framework and it applies to natural gas, oil products, coke, coal, and fossil waste, which varies on the proportion of the fuels' energy content. The tax "on fossil waste is a combined input- and output-tax, where the output-tax is levied on heat from energy production" (OECD 2018), meanwhile the tax on electricity is covered for output per MWh (OECD 2018) . There is also the so-called Carbon tax which charges 173 DKK for each ton of CO2 emitted (OECD 2019).The proportion of their application changes for fuel and users. A user can be asked to pay all of them, the payment of one does not exclude others (OECD 2018). Since the rate of taxation is variable, is possible to find stratagems that allows big companies, which make use of big quantity of energy to pay less taxes. Specifically in the bricks' market to produce new bricks cost less in terms of energy taxes than to reprocess them, this is given by the fact that the government wants stakeholders to buy bricks made in Denmark instead of buying them from abroad so to improve the Danish economy, even though this has an environmental cost (Larsen 2020).

They suggested that if the policies would be reinforced in the construction waste field, goals would be achieved faster, especially in North Jutland since there is still an old mind set of business, so stakeholders should be forced to be sustainable and none options should be given (Brandi 2020). Without further policy measures, the waste sector is expected to emit approximately 2.4 million tonnes of CO2 in 2030. This corresponds to 5.7 percent of national greenhouse gas emissions (Mads Outzen 2020).

8. Conclusion

In 2016 the C&DW was the biggest stream in Europe, so new policies were thought and adopted to have 70% of its total recovered by 2020. Denmark being part of the EU had to revisit its system to reach the goal set by

the EU, even thought it was already on the way to reach the target sets by the EU. Denmark was the first country to set policies for the recovery of waste in the 90s and therefore it considered the waste a resource to be used and not to be disposed, but as the country started to grow the waste generated by the construction industry increased. The bricks as construction material are used in the 90% of buildings facades and so it is one of the material most used in the country in the construction industry which is produced using limited natural resources. Nowadays around 47.3 million bricks have the potential to be reintroduced in the market, but instead, only 3 million are been reused meanwhile the rest is downcycled and used mostly as road fill. The practice of downcycle is and located at the end of the waste hierarchy and so not considered to be the most sustainable solution to manage the waste construction. It is also indicated by the circular economy as the last practice to adopt when the material is being recovered, since it is used when the material has not more value on its original form. Bricks could be reused as they are without any extra invading process if the right precautions are adopted during the different phases of the bricks life, which would help to improve the sustainability of the system since the practice of "preparing for the reuse" is located at the second highest level of the waste hierarchy policy and it is also used by the circular system tool has the second best sustainable solution. The paper studied the process used to produce the bricks, since it is the key to obtain specific characteristics for the bricks which must be conserved to be reused. It provides information regarding the process of downcycle and how they can be reprocessed to be reintroduced in the market. An LCA redacted for the Danish Environmental Protection Agency was used as a technical proof to sustain what is suggested by the waste hierarchy and by the circular economy system tool which is that the preparation to reuse construction material is more sustainable than their production and their downcycle since it has less impact on the environment. Different problems for each phase of bricks life cycle were highlighted and they were all related to the economy and the time constriction, the logistic aspect and lack of knowledge regarding the technical characteristic of reprocessed bricks and the luck of information regarding the availability of the product. The reporter decided to focus on the reprocessing phase of the bricks among the other phases since it was possible to give a concrete and easily applicable solution for the problems highlighted in this phase. The writer decides to suggest its applications in North Jutland since it is a market that is expanding. It is suggested the use of a newly developed machine which can quickly and efficiently sort out bricks on site.
Gamle Mursten Nord pay for the transport of the bricks from the demolition site to the factory, and the use of this machine would allow Gamle Mursten Nord to receive only the bricks that can be reprocessed and save the expenses that would occur if not reusable bricks would be transported, and additionally thanks to an improved pre-sorting, the factory would be able to reprocess more bricks at the end of the day, since it will not lose time to sort the material received. On this regards, the owner of the bricks would also save money, since the same bricks that are being transported by Gamle Mursten Nord, would have been sent by him, and therefore would cover the expensed, to the downcycle factory. Additionally, is proposed to improve the collaboration among the stakeholders on the same horizontal level using the existing platform BRN on which stakeholders can collaborate and communicate. The section dedicated to the circular economy should be updated and a new subsection should be created. In this sub section, will be possible to list the bricks that will be available as soon as a demolition happens with the purpose to sell them to be reused in a new construction. The material passport should be provided along with a picture of the bricks before being treated and after being cleaned, indicating the quantity of bricks available. Visualizing and quantify the bricks will help stakeholders involved in the design phase to choose used bricks for new constructions, since they can have a better idea of the aesthetic sense that the can give to the construction and therefore adapt the new construction to what the used bricks market offers closing the loop.

9. Discussion

9.1. Critical reflection

As with any other research paper, this report is not fool proof. One of the downsides of the conducted research was the lack of several types of data needed to fully complete the research process. Firstly, the is a lack of data regarding the production of bricks in the country, it was not possible to know how many bricks were produced every year and the quantity of raw material used to produce them. The same issue it was founded for the bricks that have been downcycled. It was not possible to give concrete numbers to these practices which would have been helpful to support the fact presented that the use of new bricks and their downcycle are the most used solutions. For this reason, the writer had to use literatures and information provided by the experts which confirmed that the approach of reprocessing bricks is among the least practices used, and the downcycle and the reuse of new bricks are the main solution used, Unfortunately the professionals interviewed were not able to give numbers. Secondly, a single LCA was used to support the theory that the reuse of bricks has less impact than downcycling them or producing them. The writer is aware of the fact that the use of a single paper to support the idea can be risky, especially because is dated, but there were no other LCA in the Danish context to support the purpose of this report. Either way the writer decided to use it since she thought that a technical proof was essential to back up of the different theories used through the report. Additionally, it was not possible to gather information about how stakeholders responded to the new technology proposed by Gamle Mursten and EPA since are not available on the paper redacted to show the results of their research and an extra interview with Claus Juul Nielsen could not be held. The writer wanted to provide an analysis of how the implementation of the machine would change the current scenario in North Jutland, but since there are no data available regarding the bricks that have been reprocessed in the region or information regarding the rate accuracy of the sorting machine, it was not possible to do so. It would have been helpful to have an analysis of the different expenses (moving bricks towards the downcycle factory and move the sorting machine towards the demolition site) to understand which would be the best solution economically speaking, if it is more convenient for the company to ship bricks to the be crushed or to ship the sorting machine to sort the material on site.

All in all, the writer believes that the current research is a well-defined starting point for providing a better understanding of the current system of the preparation for the reuse of old bricks system in Denmark, and it helps to understand that new sustainable approaches must be taken to improve the current waste construction management system.

The aim of this project was to interview different stakeholders involved in the bricks' life cycle to analyse what are the current problems that drive them not to use reprocessed bricks and to downcycle them and using what would have been said to find a common solution for everybody. Unfortunately, the coronavirus did not allow the writer to interview as many professional as wanted, so the approach was changed. Additionally, the writer found big difficulties with the interpretation of the technical information provided by the different documents, like the LCA, in the regards of bricks, since they were in Danish, and the translation was tricky and not accurate.

9.2. Further Research

Thinking ahead, this report could be used as a starting point for further research into circular economy and the use of old bricks in the Danish context, in particular in North Jutland since it looks like that more effort should be made since is a new-started-business in the region. The whole report together makes clear how new data in this market must be gathered such as the consume of raw material to produce bricks and the waste generated by them both downcycled and prepared to be reused. It should be held a new study that would compare the different impacts that the three processes have on the environment impact. It also gives the input to rethink about the policies that manage the C&DW in the country, as the professionals interviewed strongly suggested that is needed a change in this sense if a circular system wants to be achieved. This type of research helps to understand better were the specific problems are when talking about the possibility to reprocess bricks and leads to build a fruitfully circular system.

10. Table of Figure

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12. Annexes

To reach the purpose of this report and to answer the main research question, three people with knowledge regarding the production of bricks, the different processes used to reprocess and reintroduce them in the economy system where interviewed. For each of the interview an interview guide was prepared. The three guides are portrayed below.

12.1. Interview Guide I

The first interview was with Svend Roed Larse who works as consultant for the Randers Tegle and take care to talk with whoever has concerns regarding the topic. The following questions have been addressed during the interview:

1. Can you briefly explain your role within Randers Tegles and what your job entitles?
2. Could you explain what is the process followed by your company to produce bricks?
3. What is the fuel used to cook them?
4. To whom you sell them?
5. Who are the stakeholders that you work with?
6. What do you think about the opportunity to start working with reprocessing bricks instead of producing new ones?
7. Why do you things costumers prefer to use new bricks instead of old ones?
8. What types of problems do you face in your business?

12.2. Interview Guide II

The second interview was with Claus Juul Nielsen the Director of Gamle Mursten. The following questions have been addressed during the interview:

1. Can you briefly explain your role within Gamle Mursten and what your job entitles?
2. Could you tell me more about the technology that your company use to clean the bricks?
3. What do you think is the main reasons that lead stakeholders to use new bricks instead of old ones?
4. What problems does your business face?
5. Why there just a few factories that clean old bricks instead is full of production and downcycle factories?
6. Do you think that the government helps business like yours, involved in the sustainable field, to stay alive?
7. Could you give me more information about the sorting machine that you developed with the help of The Danish Environmental Protection Agency?

12.3. Interview Guide III

The Third interview was with Kurt Brandi head of department of Gumle Mursten Nord-AVV. The following questions have been addressed during the interview

1. Can you briefly explain your role within Gamle Mursten Nord and AVV and what your job entitles?
2. Can you tell me more about the partnership between Gamle Mursten and AVV?
3. Who are your costumers?
4. How do you find the bricks?
5. What is the biggest problem that you face in your factory?
6. Why do you think stakeholders tend to use new bricks and downcycle them instead of reprocessing them?
7. What do you think about the possibility of sorting bricks on site? It would help you?