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The Management of Mineral Mass Flows and Deposits and its Role in the Circular Economy

The status in the Netherlands with a brief look at Norway

Master's Thesis

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Summary

There are two problems with the current urban landscape that make it unsustainable for the future. These problems are 1) the problems of overuse and depletion of natural resources and 2) waste creation and management (Jones, 2021). The construction and demolition (C&D) industry is a large actor in this, as they are responsible for a third of the natural resources extraction (Adams, Osmani, Thorpe & Thornback, 2017) and a quarter of the solid waste generation worldwide (Benachio, Freitas & Tavares, 2019). Therefore, it is crucial to transform the current activities of the C&D industry to sustainable ones by the use of circular economies. The aim of this thesis is to put the situation in the Netherlands into context with Norway. The main research question followed in this thesis is:

What is the status of the management of mineral mass flows and deposits in the Netherlands?

This question is supplemented by a secondary research question, namely:

How does the status of the Netherlands stand in context to Norway, and how and why has the difference between the countries come to be?

The research in this thesis consists of a case study of the Netherlands, for which qualitative research methods were used. Seven respondents were interviewed for this study to obtain data. These respondents were representatives of waste processing companies, C&D companies, and the Dutch government. For the Norway part of the study, research data from the researcher's supervisor obtained through personal communication was used, as well as public online data. This is a case study of the Netherlands, put into context to Norway. The theoretical concepts of urban metabolism, circular economies and institutions and policy formed the basis for the data collection and analysis.

The empirical framework discusses three dimensions of this research. First, an extensive overview is given on the different kinds of mineral materials in the system, and how they are generally processed and disposed of. From the numbers given, it is apparent that the majority of mineral wastes are recycled in the Netherlands, and only a fraction ends up in landfills. For Norway, it seems that the recycling rate is much lower than the Netherlands. Second, the rules and policies implemented in the EU, the Netherlands and Norway concerning mineral wastes,

landfilling and C&D practices are discussed. There are multiple policies implemented to encourage circular practices. However, the rules are still lacking, allowing non-circular and even illegal practices to take place. Third, circularity within the mineral sector is discussed. This includes both current circular practices taking place, but also what the barriers to achieving more circularity are.

The Netherlands is quite far along on the road towards mineral circularity, compared to other countries, while Norway is severely lacking in that area. The first reason is geography. The Netherlands has a need for less landfilling and strict rules surrounding it because the country is small, limiting the amount of space available, and groundwater levels are high, risking drinking water contamination. Norway does not experience either of these problems. A second reason that was given, is that the Netherlands is not very rich in mineral materials, such as rock and gravel. Import of these materials is expensive, and recycling is often a cheaper option. Once again, this is not a problem for Norway. A third and last reason given, is that the Netherlands already has the required infrastructure and technology available for the processing and recycling of waste because of investments in the past, which Norway does not have.

However, the main reason that seems to determine the difference between the two countries, is policy. The policies implemented in the Netherlands are quite strict and enforce a high percentage of recycling and reuse. The policies were made with inputs from relevant actors and have been developing since the late 20^{th} century, resulting in effective and clear rules. Norwegian policies are lacking and allow for illegal landfilling activities to take place while not enforcing a high circularity rate, showing the importance of enlightened policy making over a long time span.

This thesis highlights the problem areas when it comes to implementing a more circular mineral economy. The results could contribute to finding more circular solutions for mineral wastes, by identifying where circularity is lacking and what the barriers to achieving circularity are. The case of the Netherlands is a good case. However, the case is not easy to replicate in other countries such as Norway. Norway does not have the same investments into circularity as the Netherlands, and it will take a number of years and investments to achieve a similar level of circularity. The study has revealed a significant knowledge gap in the research on mineral wastes in Norway specifically.

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Table of Contents

1. Introduction

In 2007, the United Nations Environment Programme (UNEP) established a global science-policy platform for building and sharing the knowledge needed to improve the use of natural resources (UNEP, 2022). The UNEP hereby recognised that overconsumption, the overuse of natural resources and the generation of waste are problematic when moving towards a more sustainable future and a more circular economy.

One of the areas in which de consumption of resources and the production of waste is the highest, is in the urban setting. The percentage of the population living in urban areas has increased dramatically in the past century, from 30 per cent of the population living in urban settings in 1950 compared to 55 per cent in 2018 (United Nations, 2019; Lwasa et al., 2022). This percentage is expected to keep increasing to 68 per cent by 2050. The urban landscape as it is now, is not sustainable. The challenges that make the past and current urban landscape unsustainable for the future are 1) the problems of overuse and depletion of natural resources and 2) waste creation and management (Jones, 2021). In addition to the rapid rate of urbanisation, is the fact that GDP and quality of life of people all over the world have improved drastically in the past century, and continue to do so (World Bank, 2022), and an increase in prosperity is accompanied by an increase in consumption. This combination of urbanisation and more consumption means that cities are increasingly becoming key points for (global) consumption (IRP, 2018). The growth of urban material consumption is predicted to outgrow the increase of the urban population in coming years, to reach a material consumption of approximately 90 billion tonnes by 2050 (IRP, 2018). More consumption leads to a greater use of resources and ultimately to more waste.

In order to tackle the problem of over-consumption, resource use and waste production, areas of action need to be identified within the city. These are the areas where the problem is greatest, and where the implementation of a solution will have the most effect. This is where the concept of urban metabolism comes in. Urban metabolism breaks the city down into a working metabolism with stocks and flows of resources such as raw materials, energy, water, and waste. It focusses on how these stocks and flows are used and how they move within the city (Broto, Allen & Rapoport, 2012; Kennedy, Pincetl and Bunje, 2011). There are multiple interrelated exchange processes that shape the urban environment. The aim of urban metabolism is to understand the processes behind the cities access to and consumption of resources, its digestion into several different functions, and the waste production and disposal (Kennedy, Cuddihy & Engel-Yan, 2007). By understanding the processes behind resource consumption and waste creation through the use of urban metabolism, the patterns of unsustainability can be identified and tackled.

When looking at cities through an urban metabolism lens, there is one industry that stands out as a big contributor in resource use and waste generation. The construction and demolition (C&D) industry, which creates mineral wastes, is responsible for a third of the natural resources extraction (Adams, Osmani, Thorpe & Thornback, 2017). Additionally, the industry also generates about a quarter of the solid waste worldwide (Benachio, Freitas & Tavares, 2019). This is by far the largest share out of any sector in the city. However, with the high urbanisation rates of the past decades, and the expected expansion of cities in the near future, these sectors are indispensable in the current city landscape. It is unrealistic to aim for limiting or stopping the expansion of cities, considering the urbanisation trend. Therefore, it is crucial to transform the current activities of the C&D industry to sustainable ones by the use of circular economies. However, currently the circular economic principles in projects by the C&D industry are limited, as the C&D industry mostly applies a linear economic model that is based on the principles of taking, making, and disposing of involved materials (Benachio, Freitas & Tavares, 2019; EMF, 2015). The terms mineral flows and deposits are used in this thesis. Mineral materials are the main materials that are consumed and discharged in the C&D sectors and connected industries (Lederer, Gassner, Kleemann & Fellner, 2020).

This thesis aims to aid in the research of this transition of the C&D industry to a more sustainable one, in order to tackle the problems of overuse and depletion of natural resources and waste creation and management. The aim of this thesis is to put the situation in the Netherlands into context with Norway. The choice has been made for these countries for multiple reasons. Firstly, while both countries are similar in that they are both in Europe and are near each other, the Netherlands is part of the EU, while Norway is not. Secondly, the Netherlands seems to be quite far along with its circularity, while Norway seems to be lagging behind (Circle Economy, 2022a; Circle Economy, 2022b; Circle Economy, 2022c; Norwegian Environmental Agency, 2019). This thesis aims to find out whether this is actually the case, and if so, why this is the case. The main research question followed in this thesis is:

What is the status of the management of mineral mass flows and deposits in the Netherlands?

This question is supplemented by a secondary research question, namely:

How does the status of the Netherlands stand in context to Norway, and how and why has the difference between the countries come to be?

In order to answer these questions, which in itself is quite broad, multiple sub-questions have been formulated to deal with smaller aspects of the matter in question.

1) What do the stocks and flows within the system of mineral management consist of and what does the exchange within the system look like?
2) What are the regulations and practices in place surrounding the management of mass-flows and mass-deposits?
3) How do the management practices of the mineral flows and deposits correspond to the current and future circularity aims of the involved parties?

The research in this thesis uses qualitative research methods. For the primary research question, interviews have been held with Dutch actors in the mineral waste industry. The data for the secondary research question on Norway and the EU has been obtained through secondary sources. This mainly includes interview data obtained through the researchers supervisor and online data.

The next paragraph of this thesis will discuss the theory on which the research itself is based. The theoretical framework (2) will discuss multiple concepts important to the understanding of the research and its results. The theoretical framework will be followed by the methods (3), where the conduction of the research will be explained in detail, as well as the methods by which the research has been done and the justification for those choices. After, the empirical background (4) will be presented, where the data from the thesis research is discussed. Here, the sub-questions will be answered using said data. Afterwards, the results from the research will be discussed in the discussion (5), where the main research question is answered. The thesis will end with a conclusion (6) to sum up the thesis and its results.

2. Theoretical Framework

In this chapter, the theoretical concepts used in this thesis research are explained. The concepts formed the basis for the data collection, and also for the interpretation of the results. First, the concept of Urban Metabolism will be discussed in paragraph 2.1. Second, paragraph 2.2 discusses the concept of Circular Economies. Lastly, paragraph 2.3 discusses institutions, regulations, and policy.

2.1 Urban Metabolism

2.1.1 The concept of Urban Metabolism

An economic system is made up of constant and everchanging exchange of stocks and flows of different resources between various points in the system. A concept that deals with these resource stocks and flows is ‘urban metabolism’. This concept is focused specifically on the stocks and flows within and between urban areas, and how resources such as raw materials, energy, water, and waste are used, created, and exchanged in the urban landscape. These stocks and flows consist of inputs, outputs, and storage (Broto, Allen & Rapoport, 2012; Kennedy, Pincetl and Bunje, 2011). In addition to present or current stocks and flows, urban metabolism is also concerned with the development of the exchange processes over time. Economic, political, social, and natural factors affect the development of the stocks and flows (Kalmykova & Rosado, 2015; Sanches & Bento, 2020).

When using the term urban metabolism, it is important to acknowledge its origins, which lie with the researcher Wolman (1965). He first coined the term in a study on decreasing air and water quality in American cities, where he compared the city to a living metabolism with stocks, inputs and outputs. Since its conception in 1965, the term has been used in further research and has been adapted and refined. It can be defined as *“the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste”* (Kennedy, Cuddihy & Engel-Yan, 2007: p.44). While Wolman was the first to coin the term urban metabolism, the idea of a metabolism has been in existence for much longer. Namely, it emerged with Karl Marx, who created the term to describe the relationship between humans and nature, or more specifically, an analysis of the alienation of nature, and a way in which the complex, dynamic interchange between humans and nature, resulting from human labour, is depicted (Foster, 2013).

2.1.2 Themes in Urban Metabolism

Within urban metabolism research, there have been six different themes emerging that approach the concept of urban metabolism in its own ways (Broto, Allen & Rapoport, 2012; Lucertini & Musco, 2020). The first theme is ‘the city as an ecosystem’. This approach compares the functioning of a city to that of an ecosystem. The information gained by this comparison, and the lessons learned from studying ecosystems, are used for better planning and design of cities. The second theme is ‘material and energy flows within the city’. This theme looks at how the material and energy flows through the city can be accounted for, and with which methods they can be improved in efficiency and optimised. The third theme is ‘economic–material relations within the city’. This theme is concerned with finding the material limits of the economy in order to attain stability within the use of resources and the economy. It is also concerned with policy measures, and how these can aid in finding the aforementioned stability. The fourth theme is ‘economic drivers of rural–urban relationships’. It looks at the economic relations between urban regions and the surrounding areas, and how these relations shape the distribution of flows and the creation of stocks. The fifth theme, ‘the reproduction of urban inequality’, focusses on the unequal distribution of and unequal access to the material and resource flows in the city, and who controls the processes that lead to this distribution. The sixth theme is ‘resignifying socioecological relationships’. This last theme is concerned with the potential alternative practices and socioecological relationships, and how these could affect the urban area and the stocks and flows within. The main themes of importance in this thesis through which the concept of urban metabolism has been approached, are theme two ‘material and energy flows within the city’ and theme three ‘economic–material relations within the city’. This because this thesis is concerned with material and energy flows through the city, material limits and policy.

The everyday activities of the humans occupying the space and the urban expansion of the space occupied are dependent on the use of resources, resulting in economic and environmental costs. In order to achieve sustainability, the use of the resources and the costs they entail must be reduced. Analysing the use of the resources through the concept of urban metabolism can aid in finding the ways to do this (Sanches & Bento, 2020). Thus, the concept of urban metabolism can be very useful in the pursuit to more sustainable cities and regions. There are four main purposes that the concept serves in analysing sustainability (Conke and Ferreira, 2015; Kennedy, Pincetl and Bunje, 2011). The first purpose is that urban metabolism can aid in assessing the flows of materials and energy throughout an urban area. Since urban metabolisms studies these flows, the use of the concept can give important information about energy efficiency, material cycling, waste management, and infrastructure in urban systems (Kennedy, Pincetl and Bunje, 2011). This can be useful data for urban and city planners. The second purpose is for calculating the greenhouse gas emissions of an urban region. Greenhouse gas emissions are one of the outputs from an urban metabolic system. Since many cities are currently trying to reduce their greenhouse gas emissions, the concept of urban metabolism can be a useful tool in determining the places where there is the most potential for reduction. The third application for urban metabolism is that using the concept generates models of cities and regions that can be of use to policymakers. The models can be a simulation of the potential future changes in an area and the corresponding changes in the metabolic stocks and flows. The fourth and last use is that, in addition to being a modelling tool, an urban metabolic analysis can be a tool for designing and constructing cities. In this thesis, mainly purpose one is of importance.

2.1.3 Limitations of Urban Metabolism

The concept of urban metabolism can be useful in analysing cities and sustainability. However, as with any analytic tool, the concept also comes with some challenges and shortcomings. First, the analysis of any urban metabolic system is nearly impossible when considering the system in its entirety. In a globalised world such as all urban areas are in nowadays, all urban systems are always in connection with other cities and places because of the economic world market (Conke & Ferreira, 2015). Metabolic stocks and flows of one city are dependent on the metabolic stocks and flows of other cities as well because of the economic connectedness. For example, city A can be extremely sustainable in its resource use and disposal, but that means nothing for the total sustainability if city B, where city A gets resources from, is completely unsustainable. Thus, in an urban metabolic analysis, boundaries have to be drawn to determine what is included in the analysis and in the metabolic system, and what is not (Lucertini & Musco, 2020). Because of these boundaries, some aspects are always excluded. Second, while the stocks and flows of resources, energy, wastes, and water are important factors in determining sustainability, there is often an over-emphasis on these physical stocks and flows. Other non-physical factors, such as social, economic, and political factors, are often overlooked or not fully considered (Kennedy, Pincetl & Bunje, 2011). However, these factors are inherently related to the inner and outer workings of an urban metabolic system, which means that not taking them into account in an analysis can lead to an incomplete result of the city-analysis.

2.2 Circular Economy

Urban landscapes as they are now, are unsustainable for the future. There are two challenges that make the urban landscape unsustainable, namely 1) the problems of overuse and depletion of natural resources and 2) the creation of waste and its (mis)management (Jones, 2021). In order to tackle both of these challenges, the idea of a circular economy has been proposed. A circular economy moves away from both acquiring and using virgin raw natural resources, and instead, incorporates the created wastes as the used resources for new products. The resource depletion problem is countered by not having a need for new resources, while the waste problem is countered by using the generated wastes as new resources.

2.2.1 The Concept of CE

The exact definition of the concept ‘circular economy’ is for a large part dependent on the context it is used in. However, there is a general consensus about the broad principles and the core meaning of the concept. Basic elements of circular economy are the elimination of waste and the maximisation of material values (Adams, Osmani, Thorpe & Thornback, 2017; EMF, 2015). More specifically, circular economies are economies where the concepts of ‘regeneration’ and ‘reduction of the consumption of virgin raw materials’ are central (Esa, Halog & Rigamonti, 2016). Throughout academic literature, there are four main approaches to a circular economy that have been identified: reduce, reuse, recycle and recover. To reduce entails to reduce the amount of waste produced at the end of the system, and to limit the introduction of virgin materials at the beginning of the chain. Reusing means that waste materials are repurposed, as they are, into new projects. Recycling takes the waste materials and processes them, so that new usable materials are created using used materials. Lastly, recover means that energy and other usable resources are recovered as much as possible from waste materials that cannot be reused or recycled. Throughout this thesis, the definition of circular economies given by Kirchherr, Reike & Hekkert (2017) will be used: *“an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes”* (p.229).

Because the concept of circular economy is broad, the concept has been broken down into three different levels at which it can be applied, to improve the ability to research and implement it

(Yuan, Bi and Moriguichi, 2006). The first of the three levels is the micro-level. This level is on the smallest scale out of the three. When looking at circularity options on this level, the focus is on the production area and on the individual product itself. The main actors on this level are companies and consumers. The second level is the meso-level, where the focus lies on industrial networks and the wider industrial regions. On this level, the objective is to develop an eco-friendly industrial network where the focus lies on utilising regional production systems and advancing environmental protection. Firms are important actors on this level too. However, the focus is not on what they produce and how they produce it, but how the firms are related to the wider production-network. The third and last level is the macro-level, which is the largest level scale-wise. The focus of this level is on broad networks and structures, instead of regional ones. Furthermore, this level focuses on the relations between firms and with other institutions, services, and the surrounding environment (Esa, Halog & Rigamonti, 2016; Kirchherr, Reike & Hekkert, 2017). By using the three different levels to analyse certain questions on circular economies, many different aspects of circular economies can be considered, no matter the scale. This is an advantage when introducing sustainable innovations to the current economy since actors at different scales can find the most fitting scenario. Scale is not the only category that can be found and researched within circular economies. The concept can also be researched based on the different processes and factors that shape the economy. Here, the three main distinguished categories are social, economic, and institutional (Savini, 2019).

2.2.2 Limitations to CE

The shift towards a circular economy has been offered in many scenarios as a solution to move towards a more sustainable future. However, the concept of circular economy is not flawless, and there are some challenges in its use. Korhonen, Honkasalo & Seppälä (2018) discuss multiple of these challenges. First, thermodynamic limits. This means that in a growing economic system, the eventual generation of waste, loss of energy and materials and use of new materials is inevitable, as the technologies to avoid this have not been invented and perfected yet. A truly circular economy where no new resources are added and all wastes are recycled is simply impossible as of now. A second challenge is spatial. For the economic system to become truly sustainable, it needs to be implemented at all points in the system, which is spread over the world since the economy is globalized. The system is made up out of countless actors in many different regions, all of whom have different abilities to access the necessary resources to transition to circularity. For example, actors located in the global north can more easily access certain resources than actors in the global south. Power is an important deciding factor here.

Because of this imbalance in access and power, it is more likely that circularity can be introduced into one part of the system, while another point will receive the burdens of that shift. In order to avoid shifting the burdens to other places and people, the entire system needs to be reshaped. A third problem is the problem of path dependency. Implementing circularity into an existing system is more difficult than it sounds because the current technologies are not easy to replace. The current (non-circular, unsustainable) technologies have a certain, good, market position, while the new circular technologies do not have this yet (Korhonen, Honkasalo & Seppälä, 2018). The implementation of the new technologies is thus disadvantageous for the company's market position, and requires time, money, and resources to implement. Many companies care for their market position and convincing them that spending money and resources for the sake of sustainability can be a challenge.

Furthermore, Hobson (2021) argues there is a paradox in the core of the circular economies and green growth concepts. To use systems that were created and built for an economy of extraction and accumulation for tackling the problems that these systems themselves have caused, will fail to create genuine and transformative sustainability. Hobson argues that it is this paradox that current circular solutions and interventions are stuck in but continue to use. The concept of a circular economy is often used as a political rebrand of sustainability, hindering the actual implementation of one.

2.3 Institutions, Regulations & Policy

2.3.1 What are Institutions, Regulations & Policy

The concepts of circular economies and urban metabolisms are all bounds within certain 'rules'. These 'rules' determine the parameters in which the concepts can operate and are determined by the institutions in the system. Institutions determine "*the established and prevalent societal rules that structure social interactions*" (Hodgson, 2006; p.2). This means that institutions can both be the state, but also firms or even society as a whole. Institutions have the ability to both constrain and enable the behaviour of humans within society, with officially implemented regulations or policies being the most common way of constraining behaviour.

Within research on institutions, three major pillars were identified by Scott (2013). The first pillar understands institutions in a narrow sense, in that institutions comprise sets of rules, decision-making procedures and monitoring and sanctioning mechanisms that guide human conduct (Scott, 2013; Etzold et al., 2012). Institutions as understood in this sense understands institutions as ‘regulatory rules’. The second pillar focuses on norms and values. Norms and values direct people into achieving certain goals using certain methods, in addition to deciding people’s social roles, obligations, privileges, and the power they have in society. This understanding of institution is more normative. The third pillar is the cultural-cognitive element of institutions. Every symbolic representation and the understanding of it, is determined by the culture and social environment a person is in, like a cultural or social ‘frame’. Objects, practices, and places are assigned a certain meaning that is shaped by the shared social and cultural frames of a society. These frames decide the meaning of things, but also behaviour and what is acceptable and what is not (Scott, 2013; Etzold et al., 2012).

So, while institutions can both be governmental and non-governmental, within this thesis, and within waste management, the state (government) is the most relevant institution. The state determines the law and sets up regulations which have to be followed by sectors and industry. Governmental regulations in waste management can be implemented on different scales. These scales can range from municipality-level, regional level, national level to even internationally agreed upon rules. Often, a country uses the combination of rules on different scales. For example, EU countries have to abide by rules from the EU, but the countries have their own national rules as well. Furthermore, governmental rules determine what parameters society can move within. For example, municipalities often decide whether waste separation at the source is possible. When this is possible, then it is up to the rules of society and the decisions of the individual whether waste separation actually happens.

In order to enforce public regulation, policy is written. Policy, in its most basic form, are rules written by an institution. These rules should be followed by the participants of that institution. However, policy is quite a broad concept that can be divided into multiple aspects (Colebatch, 2009). Firstly, policy implies order, system, and consistency. Actions are not careless but controlled by a prescribed formula that is universally applicable. Policy sets rules and limits to behaviour. Policy also puts a range of different activities and subjects into a common framework. Secondly, policy involved authority. Policy has the inherent backing of some authorized decision-maker. Authority makes policy legitimate. Thirdly, policy indicates a certain level of expertise. Policy is made for controlling a particular problem or phenomenon, and in order to do this, knowledge and know-how is required of both the problem area and its solutions.

2.3.2 Dutch Policy

Policy and politics in the Netherlands are defined by a concept called the polder model. This model describes the habit and tendency of Dutch policymakers to collaborate and consult with several involved political and non-political actors before making any decisions on specific policies (Cruijssen, 2020). This means that for waste policy, policymakers discuss with, for example, waste-processors and waste-producers in order to make policy about waste and landfilling. The collaboration results in a better understanding of what is needed in policies. While collaboration and cooperation are inherent to the polder model, so is compromise. This means that policies might not precisely align with the wants and needs of all actors, despite the collaborations.

Another aspect of importance is spatial planning (Hajer & Zonneveld, 2000). It is spatial planning that has contributed to the current environmental policies, among which waste policies. In earlier decades, waste was largely ignored. However, towards the end of the 20th century, there was a shift and society began regarding waste accumulation as an environmental problem that needed solving (Savini, 2019). One solution to this problem was the implementation of a circular economy, discussed in the previous paragraph. The Netherlands implemented extensive policies concerning waste and circular economies. These policies were largely motivated by the small size and large population density of the country, in which urban areas are expanding and resources such as energy, raw materials, and land are becoming increasingly scarce, thus increasing the need for good spatial planning. The Netherlands has implemented more and stricter environmental policies on all scales on waste than any other European country (Savini, 2019), motivated by both the desire for less landfilling, and the increasing need for resources. Huge investments were made into waste processing, leading to the Netherlands now having the largest waste incineration capacity per capita. Furthermore, the Netherlands also has comprehensive infrastructure and technology available for recycling processes, especially for mineral materials. Dutch environmental and waste policies have been implemented using the earlier mentioned polder model, in which the needs of stakeholders were considered as well. There has been an important focus on the need for circularity. These two factors combined have led to comprehensive policies that seem to work, leading the Netherlands to be among the best when it comes to waste processing and circularity.

The theoretical framework has been summarized in the operationalisation scheme depicted in Table 1 on page 18 and 19. Furthermore, the theoretical framework and the main concepts in it have been the basis for the code tree, in Appendix II. The operationalisation scheme and the code tree have formed the basis for the empirical background (4) and to some extent the discussion (5) part of this thesis.

3. Methods

This chapter of the thesis will discuss the methods used within the research, namely in the data collection and analysis. In paragraph 3.1, the research questions used in this research will be presented and explained. Paragraph 3.2 will discuss the research strategy and explain the choices behind the chosen strategy. The methods for the data collection of this research will be presented and discussed in paragraph 3.3, after which the methods of data-analysis will be discussed, in paragraph 3.4. The methods will also include a paragraph on the limitations brought about by the COVID-19 situation in both the Netherlands and Norway, and what methods would have been used if that was not an issue. The last section of the methods chapter, paragraph 3.5, discusses the ethical considerations in this research.

3.1 Research questions

The main research question in this master's thesis is as follows:

What is the status of the management of mineral mass flows and deposits in the Netherlands?

This question is supplemented by a secondary research question, namely:

How does the status of the Netherlands stand in context to Norway, and how and why has the difference between the countries come to be?

Considering the scope of this main question is quite large in itself, the question will be answered using multiple sub-questions. These sub-questions each deal with one aspect of the broader main question and have been formulated using an operationalization scheme which is depicted in Table 1. This operationalization scheme has been created using the theory in the theoretical framework discussed earlier. Implemented in the scheme are concepts, which are the broad theoretical concepts used; dimensions, which discuss multiple dimensions of the several concepts; and variables, which are measurable concepts in order to be able to research the broader theoretical concepts. The variables are not research questions that will be answered. Rather, the variables illustrate in which ways the data can be deciphered into valuable data.

Table 1: Operationalisation scheme

Concept	*Dimension*	*Variable*
Urban Metabolism	Stocks and flows	*Inputs:* What flows and materials are put into the system and where do they originate?
		Outputs: What flows and materials come out of the system and in what ways does recycling and disposal take place?
		Storage: How are residue materials disposed of and at what point is storage seen as the option?
	Development of exchange processes and influencing factors	*Economic*: What are the economic factors influencing the exchange flows within the system?
		Political: What are the political factors influencing the exchange flows within the system?
		Social: What are the social factors influencing the exchange flows within the system?
		Natural: What are the natural factors influencing the exchange flows within the system?
Circular Economies	Circular approaches	*Reduce:* In what ways are reduction strategies implemented in the system?
		Reuse: In what ways are reusing strategies implemented in the system?
		Recycle: In what ways are recycling strategies implemented in the system?
		Recover: In what ways are recovering strategies implemented in the system?

	Scale	*Scale*: At what scale do the circularity strategies take place?
Regulations & Institutions	Implemented regulations & policies	*Governmental rules*: What rules, regulations and policies have been implemented by the government and at which scale?
		Non-governmental rules: What norms and values are implemented because of non-governmental institutions?

The sub-questions are as follows:

1) *What do the stocks and flows within the system of mass- and mineral management consist of and what does the exchange within the system look like?*

This sub-question refers directly back to the first part of the operationalisation scheme in Table 1, the dimension 'stocks and flows' of urban metabolism. This is discussed in paragraph 2.1 of the theoretical framework. The aim of this question is twofold. The first aim is to get better insight into the actual physical mass-flows within the metabolism and to get an idea of the volumes of materials involved. The second aim is to identify how the different flows are processed.

2) *What are the regulations and practices in place surrounding the management of mass-flows and mass-deposits?*

This sub-question refers to two dimensions in the operationalization scheme in Table 1: Operationalisation scheme. It refers back to the 'implemented regulations and policies' dimension. The aim here is to get an idea of the rules, regulations, and policies that are in place for the management of mass-stocks and flows in the Netherlands, Norway, and the EU. The second dimension the sub-question refers to, is 'Development of exchange processes and influencing factors'. The factors which influence the metabolism can be based on regulations. The theory on regulations and institutions can be found in paragraph 2.3, and the theory on the influencing factors of an urban metabolism can be found in paragraph 2.1. Furthermore, this question takes the theoretical regulations discussed previously and compares them to the practices taking place.

3) *How do the management practices of the mineral flows and deposits correspond to the current and future circularity aims of the involved parties?*

The last sub-question has been formulated to put the research into a broader scale, as the other two sub-questions focussed on the lower two scales of circular economy and centred around single actors. This in order to look at the effects of the used methods onto the broader landscape. This question looks at Circular approaches and how the circular economy is developing in the countries discussed, and therefore refers back to the 'circular approaches' dimension in the operationalisation scheme in Table 1. Theory on circular economies is discussed in paragraph 2.2 of the theoretical framework.

3.2 Research strategy

In order to answer the research question proposed in this thesis, qualitative research methods will be used. According to Winchester & Rofe (2016), Qualitative research is *"concerned with elucidating human environments and human experiences within a variety of conceptual frameworks*" (p.5). Qualitative research is conducted to either understand social structures or individual experiences, which makes it different from other kinds of research. Furthermore, whereas quantitative research would be concerned with mostly numbers and data, qualitative research is mostly concerned with words (Bryman, 2012).

Although this thesis is concerned with some numbers (see research sub-question 1), it is mostly concerned with the social phenomena. Concepts such as urban metabolism and circular economies, the main theoretical concepts followed in this thesis, certainly have a quantitative and data-focused side to them. However, the context of them is found in the social setting and environment in which they are placed. Purely studying quantitative data in the case of this research would simply not yield enough information about the underlying contexts of the given numbers, and therefore a complete answer to the research questions cannot be given. It is this social environment of the concepts that this thesis is interested in exploring, and therefore qualitative research methods are the more fitting kind. The research done in this thesis is aimed at identifying underlying social structures within the management of mass-flows and mass-deposits. These social structures can help in explaining the differences found between different countries and even differences in viewpoints of how things should be done. It is for this reason that qualitative data-collection and analysis is the best choice for this research. While there will certainly be an element involved of quantitative data in the form of certain numbers and other documents, the bulk of the research done and data collected consists of interviews. The data-collection will be discussed more in depth later on, in paragraph 3.3.

This research is a case study of one country, namely the Netherlands. A case study is "*an intensive study of a single unit for the purpose of understanding a larger class of (similar) units*" (Baxter, 2016; p.130). Case studies can be used to develop and evaluate theories, formulate hypotheses, or explain particular phenomena (Vennesson, 2008). The general purpose of a case study is to eventually place the case back within the wider context or frameworks of already existing concepts and theories. However, that does not mean that a single case study is not useful or valuable on its own. The in-depth understanding about the studied phenomena in a case study can aid in solving practical or concrete problems associated with the phenomenon or help in broadening the academic understandings or theories about the studied phenomenon (Baxter, 2016). In the case of this research, the situation surrounding the management of mass-flows and mass-deposits in the Netherlands does not reflect the situation world-wide or even in neighbouring countries. However, it can provide context to the general phenomenon and broaden the knowledgebase of the subject. Furthermore, the case of mineral mass stocks and flows is a case in the wider context of the concept of both urban metabolisms and circular economies. Considering the limited current research and knowledge on the subject of mass-stocks and flows within these concepts, it provides valuable insight. While there are multiple countries involved in this research, this does not mean that it is comparative research. It is a case study of the Netherlands, which will be put into context with Norway, and to some extent the EU. The countries will not undergo a full comparison.

3.3 Data collection

As mentioned, this research uses qualitative research methods. The research consists of a case study, in which data was collected through in-depth, semi-structured interviews. Furthermore, available data on mass-stocks and flows, such as the amounts and subdivision of what kinds of materials and flows, are used as well. This section will further discuss the data and its collection. The data collection from the Netherlands case study was collected through qualitative methods in the form of interviews. The data for the contextualising Norway section of the research was collected through the researcher's supervisor, and public online data.

3.3.1 Research subjects

Within this research, three different kinds of research subjects have been approached to partake in an interview: the Dutch government, Dutch construction companies, dredging companies, and other companies working with mass-mineral flows, and waste-companies dealing with mineral wastes.

Firstly, the Dutch governmental body that determines the rules, regulations and policies surrounding the management of mass-flows and mass-deposits was approached. This is the ministry of infrastructure and water management. *Rijkswaterstaat* (RWS) is the executive organization of the ministry, which is a branch of the ministry in charge of the execution of the policies determined in the ministry. All regulations concerning mineral mass stocks and flows are determined nationally, and this governing body is the one to determine the policies. Considering this, RWS can provide the most knowledge on the current present regulations and the potential future changes.

Secondly, Dutch construction companies and dredging companies. Construction companies have the biggest share in the generation of mineral flows and wastes and are thus an important factor in researching this phenomenon. For this research, the ten largest Dutch companies in this sector have been approached. This has been done because a larger company has a larger impact on the state of mineral-stocks and flows and has more connections to other related parts of the sector. Most of the companies also have branches outside of the Netherlands, which makes it possible to question the state of the Netherlands compared to other countries or regions. Out of the ten companies that were approached, three replied. The companies that have been interviewed are KWS/VolkerWessels, Boskalis, and Ballast Nedam. An overview of the respondents can be found in Table 2 on page 23. These companies have a unique knowledge on both the generation of wastes and the recycling of products in a market-setting. They are present at both the beginning and the end sides of the production cycle.

The third and last research subject that has been approached were waste-companies dealing with mineral-waste recycling and disposal. For this, the three largest companies dealing with these kinds of wastes were approached and all three have been interviewed. All these companies have multiple locations within the Netherlands, dealing with different aspects of the waste-processing and management process. There is a mix of privately owned companies and publicly owned companies. The Dutch government is the shareholder of the company Afvalzorg, and therefore Afvalzorg is publicly owned. The other two, Attero and Renewi (and its subsidiary Mineralz) are privately owned and operated companies. All three companies have a unique knowledge on the practical side of mass-stocks and flows management and are the best actor to provide information on this.

3.3.2 Sampling methods

In this research, purposive sampling is used as the sampling method. This kind of sampling entails that respondents have been selected with the objectives of the research in mind. The selection is based on criteria with which the research question can be answered (Bryman, 2016). Furthermore, there is a distinction between different kinds of purposive sampling. This research makes use of a fixed purposive sampling strategy, where the sample has more or less been established early on in the research and little to no adding has been done to the sample as the research has developed (Bryman, 2016).

All respondents have been sought out using the internet and the websites of the companies that were approached. Emails were sent out to ten companies dealing with construction and/or dredging, three waste-companies and to RWS. The emails sent out by the researcher explained the research and asked for the most fitting expert within the company. Three of the construction/dredging companies replied, all three waste-processing companies replied, and RWS replied as well. Interviews were arranged with these seven respondents.

The final sample size of this research is seven respondents. One of these respondents is from RWS. Three respondents are from waste-companies and the remaining four respondents are representatives of construction or dredging companies. An overview of the seven respondents is depicted in Table 2.

Table 2: overview of the respondents within this research

Respondent	Representing	Kind of research subject
1	Afvalzorg	Waste-company
2	Boskalis	Dredging company
3	Renewi	Waste-company
4	Attero	Waste-company
5	KWS/VolkerWessels	Construction company
6	Ballast Nedam	Construction company
7	Rijkswaterstaat (RWS)	Governmental body

3.3.3 Interviews

The data-collection of this research consisted of six in-depth interview and one written interview with a total of seven respondents. The in-depth interviews that were conducted were semi-structured. This means that the subjects that were discussed in the interviews had been determined beforehand by the researcher. However, during the interview there was room for the respondents to answer in any way they wanted, and if there were subjects that were not pre-determined that the respondent did want to mention, they were allowed to do that (Bryman, 2016). The interview questions that were used in the data-collection of this research can be found in Appendix I, which shows a scheme that depicts both the questions themselves, the themes from the theoretical framework they belong to, and the items (concept from the different theoretical themes) from the theory that helped to formulate the different questions (Bryman, 2016).

Even though the subjects or themes of the interview were pre-determined by the researcher, there was a lot of room for flexibility. This was because the order of the questions was not pre-determined, which left space to ask questions that were not on the interview guide in the first place, providing the opportunity to follow up on previous questions when needed. In addition, it left room to change the questions, which was valuable as the respondent might have answered certain questions already or talked about one of the other themes of the interview on another answer. In this way, repetition was avoided, and more information might actually be gained than if the researcher was to follow the interview guide precisely. The questions were in the form of open-ended questions, which allowed for the respondents to give a comprehensive and extensive answer to the questions, instead of answering just “yes” or “no” (Bryman, 2016). This prevents having to follow up with questions on why the answer was "yes" or "no". More importantly, it prevents steering from the researcher themselves, which makes the answers more authentic to the respondent.

The number of respondents necessary for qualitative research differs per research and is dependent on when the theoretical saturation has been attained (Bryman, 2016). Theoretical saturation entails that no new information is given by the respondents when conducting more interviews. In the case of this research, theoretical saturation was reached as certain subjects kept coming back in different interviews, such as the recycling and disposal methods, and certain problems for circularity. The interviews also covered multiple different opinions on the state of the sector and the sustainability or circularity of it.

Most of the interviews were around 50 minutes long, with two outliers. One was shorter at 34 minutes and one was longer at around 1 hour and 30 minutes. All the respondents were interviewed using the same interview guide and questions, with little changes made to account for whether it was a waste-company or a construction-company.

However, one of the interviews was different than described above. The interview with RWS was a written interview. RWS did not agree to a spoken interview, but to a written one, as they said that a great deal of knowledge about these subjects lies with various people within their department, and thus a single person would not be able to answer the questions. The themes of the questions asked were the same, except modified to fit a governmental body instead of a company. There was more focus on rules and regulations, and less on business operations. The answers to the written interview questions will be treated the same as the data gained from the spoken interviews, with the difference being that there is no need for transcribing. Furthermore, in a written interview there is no going off the subject, so the answers will most likely be shorter than they would have been in a spoken interview.

3.3.4 Additional data

As mentioned previously, the case study of the Netherlands will be added to with data on Norway and the EU, to provide context. The data for Norway and the EU, however, has not been obtained through interviews, but through already available data. For Norway, the primary data comes from research done by the supervisor of the researcher, as well as (as of now) unpublished research papers written by him. The reasons for this are twofold. Firstly, this research is primarily a study on the Netherlands, the Norwegian data serves as context. Secondly, it is very difficult to gather data on the Norwegian case, as experienced by the supervisor. It was therefore more fruitful to invest this effort in gathering data from the Netherlands, since that is the primary research case. Furthermore, this data is supplemented by data from online databases, online information, and research papers. The data from the EU is primarily from online databases and EU publications. By using an official source for the data, it is ensured that the data is reliable and correct.

Using documents in research is different from using self-obtained data. With a document it is necessary to consider how it relates to other documents, other data, known knowledge, what the context behind the document is, and who has written and published it for what reason (Bryman, 2016). The documents used in this research are assessed in relation to the context of the study and what is said in all interviews. For the document data from the Netherlands that will be obtained, it was examined whether the document corresponds with what was said in the interviews, and with which points of view and parties the documents fit and/or correspond. In this way the bias is kept to a minimum. However, the documents are a secondary source of data, and the interviews are seen as the most important in this study.

3.3.5 COVID-19

A few changes from the ideal research-collection methods were necessary because of the COVID-19 situation in both the Netherlands, where the research collection took place, and Norway, where the researcher and the researcher's university are situated. The data-collection was originally supposed to take place in January of 2022, as the researcher was in the Netherlands at the time to conduct face-to-face interviews. However, as of the end of December 2021, the Netherlands went into a complete lockdown as a result of the high number of COVID-19 cases in the country. As there was no indication when the lockdown would end, there was no opportunity to plan the interviews. By the time the lockdown was lifted, the researcher had gone back to Norway, and was not able to conduct the interviews face-to-face.

Instead, all the interviews have taken place via video-connection, using Microsoft Teams. These interviews were recorded using a recording software approved by the University of Oslo (UIO) and the Norwegian Centre for Research Data (NSD). Even though the COVID-19 situation made alterations to the research, it ultimately had no effect on the outcome of the research and the research was mostly conducted normally. This might be attributed to the fact that the world had been in the pandemic for two years, and people are now more used to having to work around the rues and regulation for COVID-19.

3.4 Data analysis

3.4.1 Coding

After the collection of the research data, it needs to be analysed in order to be able to say something about it. After conducting the interviews, they were transcribed in its entirety into text. These transcriptions were then coded. Coding is a form of data analysis that breaks down the data into codes, which are words or short phrases that symbolically assign an attribute to a portion of the data. This attribute is assigned to identify the meaning, summarize, or highlight the importance of that portion of text (Saldaña, 2009). Within coding qualitative data, there are Cope (2016) defined three main purposes. The first purpose is to reduce the data collected and to make it more abstract. The non-important information is filtered out, which makes it possible to focus on the important parts of the data, in this case the interview transcripts. The second purpose is to organise the collected data. By doing this, the necessary data can be filtered out and used more easily. The third and last purpose of coding is to analyse the collected data so the information that has been gained through the data collection becomes identifiable.

One thing that is important to keep in mind when using the method of coding, is that coding is an inherently interpretative process. How the data from the transcripts is interpreted is influenced by underlying assumptions of the researcher, as well as by their subjectivities and predispositions. These underlying steering mechanisms influence the coding-decisions made (Saldaña, 2009). It is important to be aware of the decisions one makes when coding, and what the reasoning behind those decisions is, so that they can be acknowledged as decisions (Braun & Clarke, 2006).

Two types of coding have been used in this research: open and axial coding. Open coding is a broad method in which text fragments from the transcribed interviews are given specific labels. In axial coding, the labels from the open coding are compared and the labels that belong together or are similar are given the same overarching code (Bryman, 2016). While processing the data, it is important to keep a good overview of the different concepts, as they work with the interpretation of people's experiences. This interpretation shows connections between experience and theory. The labels and codes for the coding have been determined on the basis of theory and the operationalization (Table 1) and can be found in the coding scheme (Appendix II). In this way, the researcher sought to keep the interpretation of the interviews as objective as possible. The coding of the transcripts was first done by hand, in order to get a better overview of the data and the information and which codes would be used. Then, using the coding computer software Nvivo 12, the final coding was done. It is a personal choice of the researching how to code and whether by hand or using a computer program is the best method. In the case of this research, a combination was used in order to get the best possible result for analysing the data.

3.5 Ethics

3.5.1 Rigour

One important aspect of scientific research is the possibility for the research to be evaluated by informants and colleagues. Therefore, one element that should be considered when doing research is rigour. Ensuring rigour means that the research is trustworthy and dependable (Stratford & Bradshaw, 2016). This is accomplished in several different ways. Firstly, trustworthiness needs to be ensured throughout the entire process, and methods for ensuring it should therefore be applied at multiple stages (Stratford & Bradshaw, 2016). Secondly, every stage of the research should be documented carefully, so that it is possible for others to check the work that has been done. Furthermore, documenting the research ensures that other can understand the thought-process and interpretation of the data, in order to justify the data.

In this research, rigour has been ensured in different ways. In the early stages, the research has been framed with a theoretical framework. By doing this, the research in this thesis is put into relation with other existing theories and concepts widely recognised as significant (Stratford & Bradshaw, 2016). A theoretical framework also gives context to the chosen case study and shows how this particular case can add to existing theory (Monk & Bedford, 2016). Furthermore, the theoretical framework is the basis of the interview questions and coding that has been done.

A second way in which rigour has been ensured in this research is through the concept of triangulation (Stratford & Bradshaw, 2016). This research includes multiple respondents with different perspectives on the management of mineral flows and wastes. Furthermore, documents and data from different sources and perspectives have been used. In order to support the research and create a basis for the interview questions as well as the codes, multiple theories have been used, which are explained in the theoretical framework (2). Lastly, the research was checked and reviewed by the thesis supervisor and by peers at multiple stages of the process.

3.5.2 Ethical considerations

Researchers are always confronted with ethical dilemmas when doing research. This is especially true for research for which the main sources of data are humans. To ensure this research and the collection of the data used in it is ethically sound, several precautions have been implemented.

First and foremost, it is important to have the informed consent from all of the respondents involved in the research (Patton, 2002). Before the interviews took place, in the contacting phase of recruiting the respondents, the purpose of the research and the positions of the respondents were clearly communicated (Dowling, 2016). Their consent was established through a consent form that was sent out to the respondents before conducting the interviews. This form also had information on the research. Only if and once the form had been signed, did the interview take place. During the interview, consent was once again asked to start the recording of the interview. In this way, the ethical choices made can be checked by third parties, and the researcher can be held responsible.

Second, confidentiality was guaranteed to the respondents. In extreme cases, the researcher is legally not allowed to hold back information (Patton, 2002), however that was not an issue within this research or data collection. The interviews were confidential as the personal information of the respondents, like their names, were not included anywhere in the research, including the transcripts. This means that the respondents were anonymous to anyone reading the final thesis (Dowling, 2016).

Third, the recordings of the interviews were deleted completely after the interviews were transcribed. This limits the risk of people accessing the recordings, and since the transcripts are anonymous, anonymity can be ensured. The data has been stored on an external hard drive, not on a personal device. The transcriptions were accessible, but only for parties that have a need for it (e.g., persons checking and verifying the research methods). The transcripts were accessible to the respondent with whom the interview was held. They were not accessible to the other respondents.

4. Empirical Background

This chapter of the thesis will discuss the analysis of the data obtained in this research and the results of the research. The three sub-questions, which have been discussed in paragraph 3.1, are the basis for the structure of this chapter. The first paragraph in this chapter will discuss the different stocks and flows in the system, while also discussing the methods of disposal. The second paragraph will discuss the regulations and policies concerning mineral wastes and deposits in the Netherlands, Norway, and the EU. The third and last paragraph will discuss the environmental effects of the subjects, the future situation, and will tap into circular economies more in-depth.

4.1 Mineral Stocks and Flows

The sub-question that will be answered in this paragraph is as follows:

> *What do the stocks and flows within the system of mineral waste management consist of and what does the exchange within the system look like?*

This paragraph will provide an overview of the different mineral stock and flows that are present in the metabolic systems of the Netherlands and the Oslo-region respectively. The different mineral materials that go through the waste-processing system will each be discussed in their own paragraph. Furthermore, the amounts of the materials going through the system will be discussed. The amounts from the Netherlands were obtained through personal communication with the Dutch Government, who sent a file with the exact numbers from 2013 to 2018, as this is the most recent available data. The Norwegian data is obtained from the Norwegian central bureau of statistics (SSA). In addition to the kinds of materials, the method of processing will also be discussed.

As discussed in the theory on urban metabolism in paragraph 2.1 of the theoretical framework, stocks and flows can be divided into three separate categories, the inputs into the system, the outputs from the system, and deposits, where materials are not actively in flow but in wait. Because this thesis deals with waste-management, the inputs-and outputs will be considered as one, as the inputs into the system ultimately create the waste-materials that come out of it. The separate materials that come into and out of the system are not the main focus, but more so the materials that flow through the system. The inputs and outputs from the mineral system, will be explained in this paragraph, as separate materials.

Figure 1, depicted below, shows the identifiable flow of mineral materials through the system. This scheme could be considered as a simplified version of the metabolism of mineral materials in the urban system. Since mineral materials are consumed and discharged in the C&D sector (Lederer, Gassner, Kleemann & Fellner, 2020), it makes sense that construction projects are the beginning of the chain. This includes construction of buildings, both public and private, infrastructure construction, and nature construction and maintenance (such as the construction of gardens, parks or the dredging of canals and other bodies of water). From these construction projects, waste is generated. This waste is then processed by waste processing companies, where it is either reused, recycled, or recovered, or it is deposited into landfills. The recycling process also produces residuals that cannot be reused, which are also deposited into landfills. Often these materials are contaminants, which is why they cannot be reintroduced into the system. Once the landfills are full, it is possible that once they have been properly sealed off, the land is repurposed for other uses.

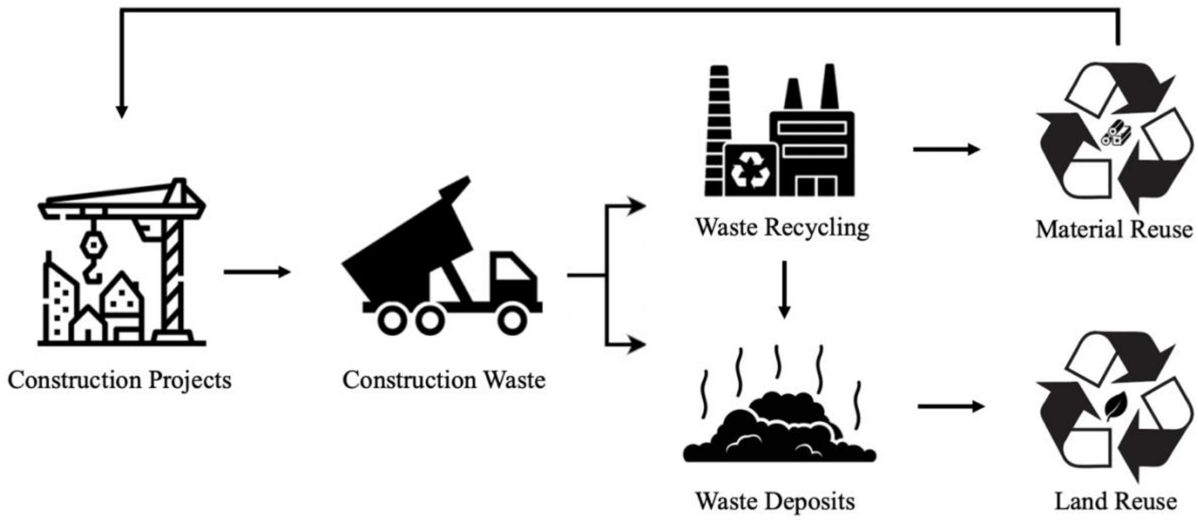


Figure 1: the material flow in the system of mineral waste materials.

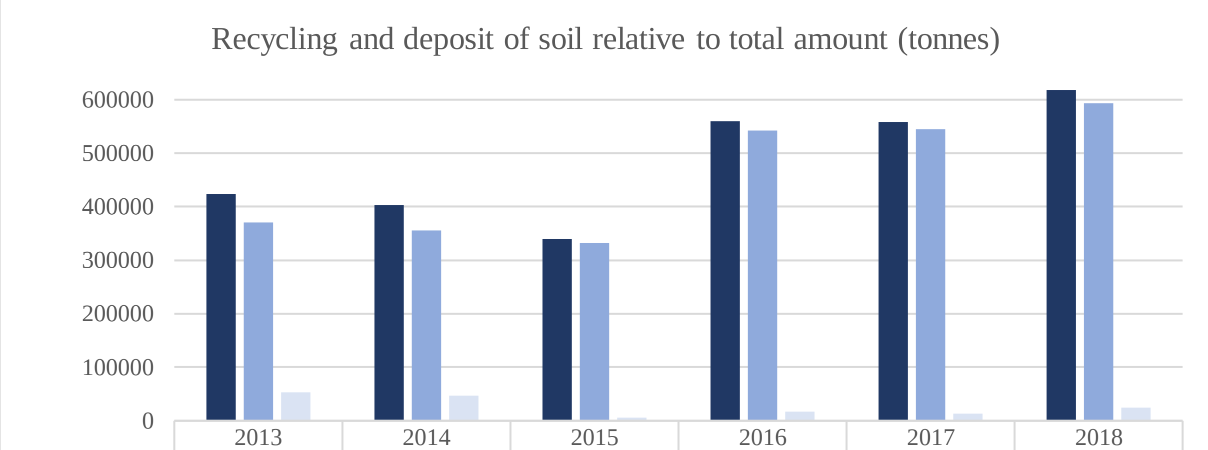
As mentioned earlier, mineral waste is quite a vague term, as some consider certain materials as minerals, while others do not. In this thesis, mineral materials are the materials that are consumed and discharged in the C&D sectors and connected industries (Lederer, Gassner, Kleemann & Fellner, 2020). The exact mineral materials that come out of the urban metabolic system into waste management will be discussed separately in this paragraph. in correspondence with RWS, eight different materials were identified as mineral wastes in the Dutch system. These materials are: ferrous metal waste and scrap, non-ferrous metal waste, mixed ferrous and non-ferrous metal waste, wood waste, concrete, stone, and plaster waste, hydrocarbon-containing road surface waste, mixed building waste, and soil. In addition to these materials identified by RWS, there is one more material that was identified through the interviews held with companies in this thesis research. This material is incinerator ashes, which is not necessarily considered mineral waste, but it goes through the same process and poses the same problems as mineral wastes. Since this material was an important topic in the interviews, it will also be taken into consideration. The choice has been made to follow the Dutch categories of mineral wastes, as there is less data and less categories available for Norway, however, where possible, the Norwegian data on the specific materials will be given as well. The data on Norwegian wastes only includes the amount of waste and not how much of it is recycled and deposited. These numbers are unknown.

4.1.1 Soil

Soil is one of the main flows when it comes to minerals. The majority of this stream is put into the recycling system and is reused after recycling. Only a small part goes to landfills and a tiny fraction is used for other uses, however, this fraction is so small that it is negligible. The data available on soil amounts comes from the Dutch government and covers the flows within the Netherlands. The amounts are visible in the graph depicted in Figure 2. There is no data available on Norwegian/ the greater Oslo region's soil wastes, neither for recycling nor deposits.

When processing soil, there are two possibilities. The first possibility is to dump the soil into a landfill. This method is not circular at all, and the soil will not be reused for new purposes. The second more circular method is to put the soil through a recycling process, where in the end the soil is clean and ready for reuse. When looking at the soil-recycling process there is four different methods. Each method has its own advantages, disadvantages, and is tailored to a specific kind of soil. The latter is important when soils contain certain contaminants that have to be removed for repurposing.

Extractive cleaning is the most common form of soil cleaning and because of this, it was the most mentioned form in the interviews. It is a method by which soils go through a multitude of



	2013	2014	2015	2016	2017	2018
Total	423566	403565	338981	560297	558149	617802
Recycled	370359	355995	332620	542741	544273	593262
Deposited	52873	46662	6354	17547	13872	24535

Figure 2: Table depicting the recycling and deposit of soil relative to total amount.

sieves and cyclones in order to sieve out the contaminants, such as metals and course materials such as rocks and pieces of wood. There are also installations that use water and pressure to get the same result. There are two end materials coming out of the installation. On one side clean sandy soil comes out, and on the other side the residue: dry sludge that has been pressed together, also named sludge cake:

> *"We also take in contaminated soil. We only have an extractive cleaning installation. The extractive cleaning installation is actually a rinsing machine, so we have a dry sieve, so dry sieves to get the physical contaminants out of the soil to see if it is suitable for reuse afterwards, and we also have an extractive cleaning installation and it does exactly the same, only with water and pressure and a lot of sieves and cyclones. And that pulls the organic matter and the clay fraction out of the soil, and then you are left with only the grain of sand, the inert fraction"* (Translated by author) (Interview 4).

In order to use an extractive cleaning installation, the soil that is cleaned has to be sandy. Clay particles are too small and retain too much water for the sieves and cyclones. Particles bigger than sand are too big, causing excess material to not properly be taken out:

> *"Then you have what we do, which is called extractive cleaning, which is commonly named washing the soil, you do that with water. There has to be sand in the soil, otherwise it's not very useful. In the Netherlands we live in a river delta, so the soil*

is quite sandy. Hence, the soil is very well suited for this" (Translated by author) (Interview 2).

Extractive cleaning is used on soils that have been contaminated by other mineral materials, such as metals, rocks, and wood. Sieving and washing is enough to take these contaminations out. For materials containing more toxic contaminations, more extensive cleaning methods are used.

A second option for recycling soil is through biological cleaning. This technique breaks down contaminants in the soil using micro-organisms such as bacteria and fungi. Contaminants are mineralized, and pollutants such as oil are turned into CO_2 and water. In this way, compounds that are harmful for the environment are converted into non-harmful compounds, making the soil reusable:

> *"Due to the biology of the soil, a breakdown takes place of especially light oil components, and that leads to the soil being cleaned to reuse standards."* (Translated by author) (interview 2).

A third option for recycling soil is thermal cleaning methods. Thermal cleaning is used for soils that cannot be cleaned using extractive or biological methods, because the contaminations in the soil are too heavy to be removed using the less intensive methods. It is used for the removal of organic contaminants, such as oil or polycyclic aromatic hydrocarbons (PAHs):

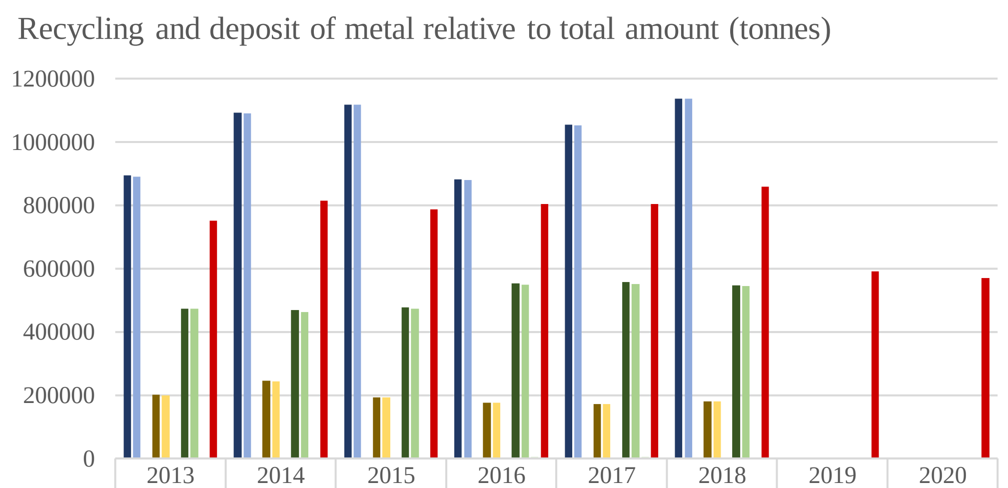
> *"Thermal soil cleaning, so soils with organic contaminants such as oil and PAH, those soils are heated at a temperature of about 600 degrees, so then the organic components move to flue gas, which is then cleaned as well, and then what is left is thermally cleaned soil"* (Translated by author) (Interview 2).

The fourth and last commonly used method for recycling soil is immobilisation. This is arguably the least circular or environmentally friendly method of the four techniques mentioned. With this method, the soil is mixed with certain binding agents and cement, to form a kind of concrete. This concrete can then be used in new building projects. While this method recycles the soil into a new usable product, the reusability or recyclability for the future is not as high as it would be for cleaned soil.

4.1.2 *Metal waste and scraps*

When metals arrive at a waste-processing plant, they are separated using magnets and special sorting machines. Looking at metal waste, there is three distinctions based on what substances the metal is made up of. The main distinction here is whether the metal is ferrous or not, that is to say, whether the main substance of the metal is iron. RWS divides metal waste into three categories: ferrous metal waste and scrap, non-ferrous metal waste, and mixed ferrous and non-ferrous metal waste. The metals are separated as much as possible, so they can be molten and reused for the designated purposes.

In addition to recycling and depositing the metal waste, metal wastes are also partly incinerated in the waste incinerator, because not every piece of metal can be recovered and separated. Additionally, some of the metal is used in energy recovery, where waste is burned to create energy in the form of electricity and warmth. While recovery is one of the methods of circularity, these amounts are not significant enough to include in the graph. The total, recycled, and deposited amount of metal waste and scraps, divided into ferrous, non-ferrous, and mixed, is depicted in Figure 3.



	2013	2014	2015	2016	2017	2018	2019	2020
Total ferrous	893744	1092011	1118605	882600	1055271	1136787		
Recycled ferrous	891228	1091333	1117959	879044	1051582	1136483		
Deposited ferrous	315	628	615	1975	2,014	268		
Total non-ferrous	200928	244873	193134	175299	172582	180561		
Recycled non-ferrous	199722	244340	193121	175189	172513	180236		
Deposited non-ferrous	494	502	13	110	69	261		
Total mixed	473970	469110	478189	553943	556317	546622		
Recycled mixed	472398	463335	474076	548144	550073	545697		
Deposited mixed	153	12	28	4527	4858	547		
Norway Metal Total	751000	815000	786000	804000	804000	858000	592000	571000

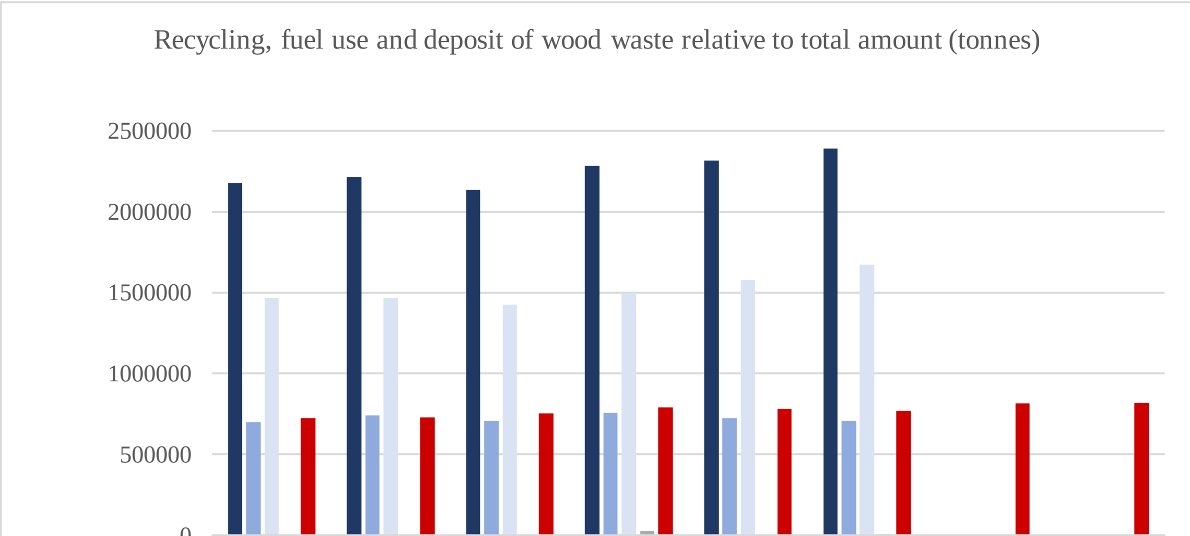
Figure 3: Recycling and deposit of metal relative to total amount (tonnes).

The Norwegian data does not distinguish between ferrous and non-ferrous, but there is data available on the total amount of metal wastes. This data is also depicted in Figure 3. Only the last category "Norway Metal Total" is Norwegian data, the rest is Dutch.

4.1.3 Wood waste

Wood waste is different from other wastes such as metal or soil, since the composition does not allow it to be melted or change its shape in any way, except for being made into smaller pieces. When the wood waste arrives at the processing plant, the wood is divided into three kinds: 1) A-wood, which is high quality wood that has not been painted, treated, or impregnated; 2) B-wood, which is medium quality wood that has been painted or glued, but not impregnated (Renewi, n.d.); and 3) C-wood, which has been impregnated, which means it contains chemical substances. The last kind of wood is not reusable.

A-wood and B-wood is both used in the recycling process, where it is chipped into smaller pieces. These pieces are either pressed together to make products like particle boards, MDF, or pallets, or they are used as for example ground cover. Furthermore, the wood is also used in the energy recovery process, where the wood serves as a fuel in order to generate energy and heat. The amount of wood waste used for recovery is much larger than other waste-products. The



	2013	2014	2015	2016	2017	2018	2019	2020
Total	2176782	2211677	2135534	2282675	2314166	2389269		
Recycled	701307	742262	706592	758327	726205	706426		
Fuel	1466741	1465022	1426418	1494170	1578286	1671700		
Deposit	3091	1220	682	28720	381	5837		
Norway Total	726000	727000	752000	792000	784000	769000	815000	818000

Figure 4: Recycling, fuel use and deposit of wood waste relative to total amount (tonnes)

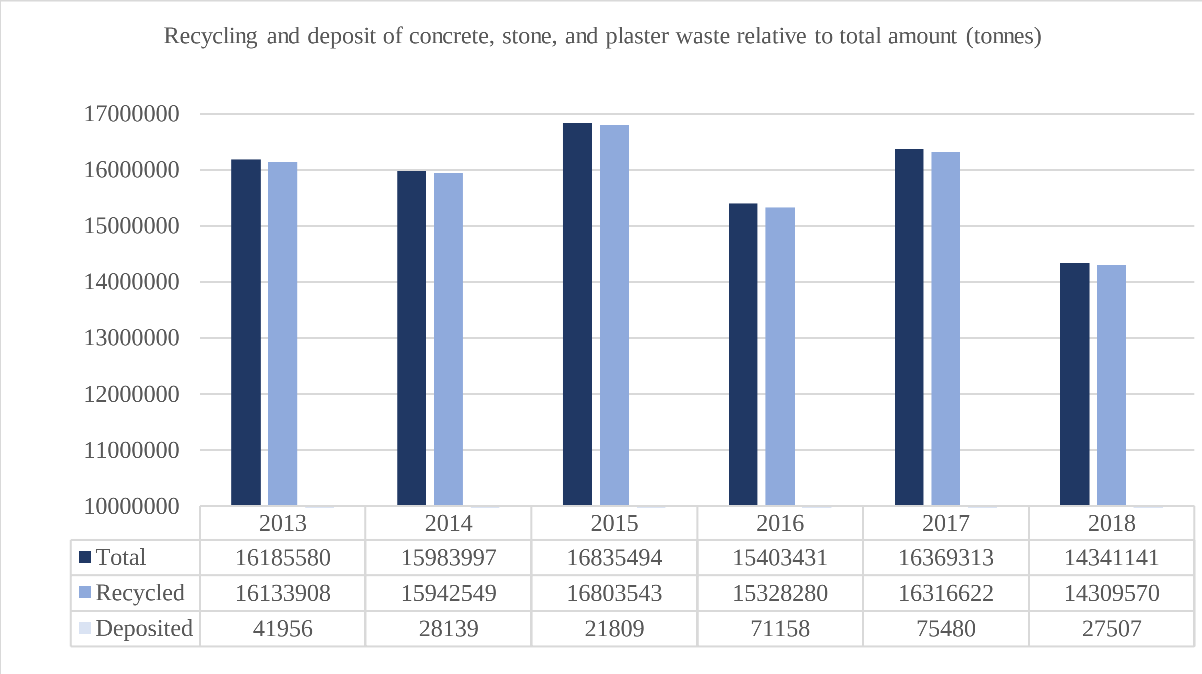
exact amounts of wood waste, and what is recycled, recovered, and deposited is visible in the graph depicted in Figure 4. ‘Total’, ‘Recycled’, ‘Fuel’ and ‘Deposit’ are the numbers on Dutch wood waste, while ‘Total Norway’ is the available Norwegian data.

4.1.4 Concrete, stone, and plaster waste

The stream of concrete, stone, and plaster waste is the largest of the waste streams classified by RWS by quite a margin. These materials have been pre-sorted, and arrive at the plant as pure concrete, stone, or plaster. Not all of the waste is sent to the waste-processing plant, as the factories of products made from these materials are willing to take back and reuse leftover materials, as long as they are undamaged:

> *"In the dismantling phase you can ensure that you have a separate container for, for example, your drywall and the waste from your drywall during that short period of dismantling. That goes in a separate container. But that container, with nice plates that are not contaminated with other materials, those ones the factory wants back. We don't mind, they just grind it, it just goes back into their circuit. But if there are all kinds of polyurethane sealants and other junk in it, then it becomes a bit more difficult. So, if you let a separate container run along during that construction phase, specifically for those plasterboards, to name just one example, you also get that material back. The same for concrete, stone, or other materials. The factory wants those materials back as long as they are not contaminated with other materials"* (Translated by author) (Interview 6).

The majority of concrete, stone, and plaster waste is recycled and reused again. Either the concrete, stone or plaster was undamaged enough to be reused in its original purpose in the construction industry, or in case it is damaged, it is pulverised and made into new products, such as new cement or concrete. The amounts of concrete, stone, and plaster waste can be seen in the graph depicted in Figure 5.



	2013	2014	2015	2016	2017	2018
Total	16185580	15983997	16835494	15403431	16369313	14341141
Recycled	16133908	15942549	16803543	15328280	16316622	14309570
Deposited	41956	28139	21809	71158	75480	27507

Figure 5: Recycling and deposit of concrete, stone, and plaster waste relative to total amount (tonnes).

The categories in the Dutch and Norwegian data are slightly different. For metal and wood waste, this was not a problem as these categories were similar or even the same. However, for this category that is not the case. The Dutch put concrete, stone, and plaster waste into one category. The Norwegian category is "concrete and brick", which is similar, but not the same. For this reason, the numbers will not be depicted in the same graph. Instead, the numbers are depicted in Table 3:

Table 3: Overview of total concrete and brick waste in Norway from 2013 to 2020.

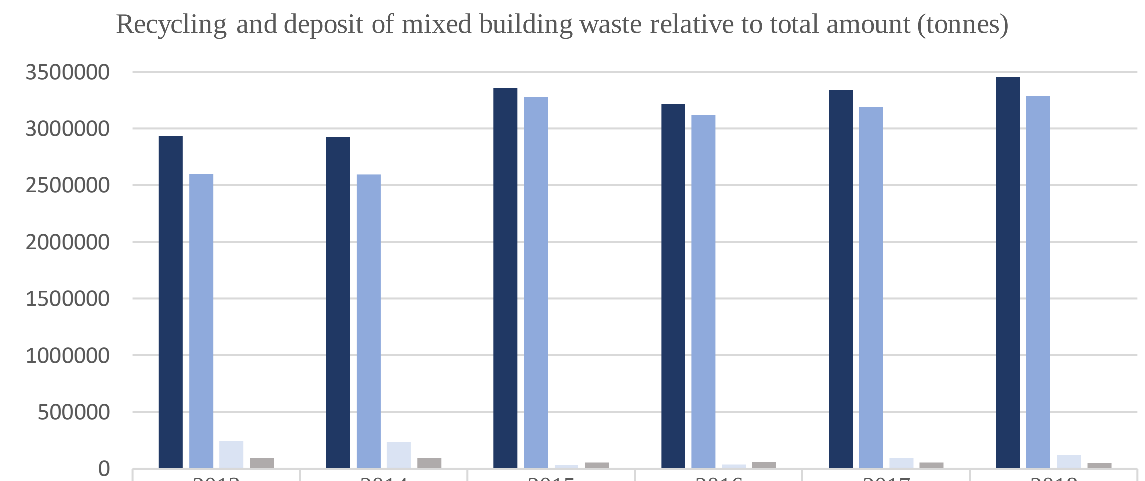
Year	2013	2014	2015	2016	2017	2018	2019	2020
Concrete & Brick x1000 t	810	904	893	989	1074	1169	1474	1467

4.1.5 mixed building waste

With mixed building waste, there are a lot of different materials involved. These materials get separated as much as possible, after which they are processes according to the material they are. These materials are for example wood, plaster, rubble, and metal. Another flow is called sieve sand, which is the smallest fraction created by construction projects. This flow goes through the same cleaning system as soil does, even though it is not considered soil:

"Another flow, that is not contaminated soil, but also a flow that is regularly released, that is called sieve sand. That is sand from construction and demolition waste. Construction and demolition waste, if a building is demolished then you have a lot of waste wood, stones, concrete, but in the end a fine fraction also remains, and by fine, I mean a fraction smaller than 10 mm, 1 cm, that's called sieve sand. That is actually for a very large part mineral, which we also clean, which is also an important flow" (Translated by author) (interview 2).

While the majority is still recycled, this percentage is lower than with the concrete, stone, and plaster waste, because there is more material that is contaminated and thus not recyclable. Furthermore, a larger percentage goes to landfills. From concrete, stone, or plaster waste, about 0,19% was deposited, while from mixed building waste about 1,3% was deposited (data from 2018). In both cases the percentage is small, but about ten times as much waste goes to landfills with mixed building waste. Additionally, part of the mixed building waste is used for energy recovery (between 0,8 and 8%), where it serves as fuel to create energy and heat. The absolute amounts of mixed building waste can be seen in the graph in Figure 6. There is no data available on Norwegian/ the greater Oslo region's mixed building wastes, neither for recycling nor deposits.



	2013	2014	2015	2016	2017	2018
Total	2939199	2926890	3358934	3218058	3342353	3455012
Recycled	2600314	2597081	3276490	3119468	3192091	3290963
Fuel	244607	235733	29927	35611	96250	117260
Deposited	94209	93886	52389	62084	53116	46334

Figure 6: Recycling and deposit of mixed building waste relative to total amount (tonnes).

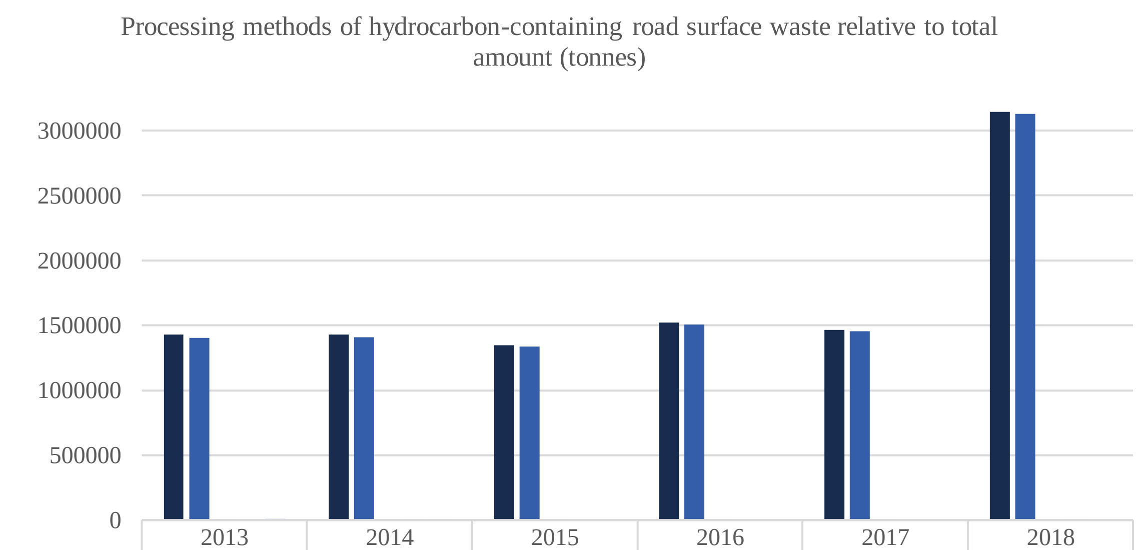
4.1.6 Road surface waste

The last category for which there is precise data available from the Dutch government, is road surface waste, or more specifically hydrocarbon-containing road surface waste. This is more commonly known as asphalt, both tar-bearing and non-tar-bearing. A small percentage of the road surface waste is used for fuel, a small percentage is incinerated, and a small percentage goes into landfills. However, by far the majority of it (between 99 and 100%) is recycled and used in new asphalt:

> *"The asphalt that comes from road construction. That is a lot of course. We do not see that as waste, because it actually goes directly back to the asphalt factories and is more or less 100% recycled and used in new asphalt"* (translated by author) (interview 6*).*

New road construction projects in the Netherlands usually use a certain percentage of recycled asphalt in the asphalt that is laid. This percentage is around 50 per cent:

> *"I think we produce and process 600,000 tons of asphalt a year, and in that asphalt, we process about 50 percent, we call that PR, Percent Recycled asphalt, when we*



	2013	2014	2015	2016	2017	2018
Total	1428459	1428703	1348697	1522788	1465675	3141827
Recycling	1404398	1406527	1338672	1508331	1454904	3128450
Fuel	6952	7046	6595	8814	6574	7224
Incinerated	7340	8296	2641	5037	3661	5452
Deposited	9769	6834	242	137	266	478

Figure 7: Processing methods of hydrocarbon-containing road surface waste relative to total amount (tonnes)

> *have roads and we break them up, [..] and it is reduced in size. Then about half of the annual production is reused"* (Translated by author) (Interview 5).

The absolute amounts of hydrocarbon-containing road surface waste can be found in the graph depicted in Figure 7. Since the amounts used for fuel, incineration, and deposits are more or less the same, all three have been included in the table, even though in comparison to the amount that is recycled they are relatively insignificant. There is no data available on Norwegian/ the greater Oslo region's road surface waste, neither for recycling nor deposits.

4.1.7 Incinerator ashes

The final category of materials that will be discussed in this chapter, are incinerator ashes. Incinerator ashes are the result of waste incineration, which is used for household waste and mineral wastes. The ashes that remain after incineration are reprocessed and put through a machine which removes all metals from it, such as iron, aluminium, copper, gold, silver, and platinum. The metals can then be recycled separately. The part of the ashes that remain after the metals and other recyclable bits have been removed often contain contaminants or even toxic parts, as it is the remnant of everything that is thrown away by people, and people are not always the most rigid when it comes to separating waste. For example, batteries are thrown out in household waste when this is not allowed. Because contaminants or toxic parts cannot be reused in the circular economy, these remnants often end up in landfills. However, as of 2021, a limit has been set on the amount of incinerator ash that is allowed to go into landfills in the Netherlands:

> *"In the case of bottom ash, a certain rule has been introduced from 2021 onwards, a maximum of only 15 percent may only be landfilled, in other words the reuse from bottom ash is at least 85 percent"* (Translated by author) (interview 2).

This means that even though the ashes may contain contaminants, they have to be mostly reused. The method that is often used for recycling these ashes is immobilization, as this is a method of recycling where contaminating substances are not leaking back into nature. Furthermore, other methods used for soil recycling can also be used to clean the ashes and get rid of contaminants. It is then possible for the ashes to be used in certain projects and certain ways, depending on the contamination level left in the ashes or soil.

Even though this material is not considered a mineral material, it was an important topic in multiple interviews conducted for this research. For mineral waste processing plants, this material is processed through the same methods and considered as similar. However, it was not included in the numbers obtained by RWS. Furthermore, the data on the numbers is not available on the website of the Central Bureau of Statistics of the Netherlands (CBS). Only primary waste is included in order to avoid double counting, and as incinerator ashes are the remnants of other wastes, they are secondary wastes. However, it was possible to get a rough number from the interviews, which is close to two million tonnes a year in the Netherlands:

> *For activities such as incinerator ash reprocessing, I don't know if you've delved into that, that is also a big bulk flow, two million tonnes a year is released just in the Netherlands"* (Translated by author) (Interview 1).

> *"And incinerator ashes, that is about 1,8 million tonnes a year"* (Translated by author) (Interview 2).

As there is no official statistics on incinerator ashes, it is not sure how much ends up in landfills and how much is recycled. However, because of the new law introduced in the Netherlands, it is known that this number is no higher than 15 per cent of the total amount of incinerator ashes.

In Norway, there are statistics available on the amount of incinerator ashes produced in the country. In 2020, this number was 639,000 tonnes (SSB, 2021), and includes slag, dust, incinerator ashes and fly ashes. This is significantly less than the Netherlands's 2 million tonnes. This difference can be attributed to the different number of inhabitants (Norway's 5 million compared to the Netherlands's 17 million), but also to the relatively large incineration capacity of the Netherlands:

> *"The space we [the Netherlands] have is scarce. [...] And that is also one of the reasons that they said that we should all start building incinerators here in the Netherlands as soon as possible. We have by far the highest percentage of incineration in the Netherlands. Well that all happened in the nineties, that they said we should stop depositing waste and it should all be incinerated, that which is able to be incinerated of course, but you see that incinerating waste also comes*

with all kinds of problems. You will have that incinerator ash left over, and you have to do something with that" (Translated by author) (Interview 1).

4.2 Regulations and Practices

The sub-question that will be answered in this paragraph is as follows:

What are the regulations and practices in place surrounding the management of mass-flows and mass-deposits?

This paragraph discusses the rules and regulations in place surrounding the depositing and recycling of mineral wastes. While the practices are mostly in line with regulations, there are still differences, especially when comparing countries. First, the regulations implemented by the EU are discussed. Thereafter, regulations and practices in both the Netherlands and Norway will be discussed separately. This paragraph gives examples of the theoretical concepts of institutions, regulations and policies discussed in paragraph 2.3 of the theoretical framework.

4.2.1 European Union

In 2008, the EU released a directive for waste management. The EU defines a directive as "*a legislative act that sets out a goal that all EU countries must achieve. However, it is up to the individual countries to devise their own laws on how to reach these goals*" (European Union, 2022[1]). Directive 2008/98/EC (2008) established a legal framework for the treatment of waste within the EU. In this directive, several measures were created that are important within this thesis, namely for waste-processing practices. The directive provides a hierarchy in what methods for waste management will be prioritized: 1) prevention, 2) preparing for reuse, 3) recycling, 4) other recovery (e.g., energy recovery); and lastly 5) disposal. A depiction of this hierarchy framework is given in Figure 8 below. Furthermore, the directive made it obligatory for national authorities to establish a waste management plan and waste prevention programmes. Lastly, the directive introduced a target that was to be achieved by 2020 for the recycling and recovery of wastes. This target was 50 per cent for household wastes, and 70 per cent for C&D waste. In 2018, an amendment was made to the 2008 directive, Directive 2018/851 (2018), in order to include more circular strategies and to pave the way for strategies

[1] https://european-union.europa.eu/institutions-law-budget/law/types-legislation_en

Figure 8: Depiction of the waste hierarchy as set by the EU. Source: European Comission (2022)

towards a more circular economy in the EU. The directive strengthens the rules on waste prevention. While it does not set new targets for household or construction and demolition waste specifically, it does set new municipal-waste-recycling targets, namely that by 2025, at least 55% of municipal waste will have to be recycled. This target will rise to 60% by 2030 and 65% by 2035.

In addition to directives on waste management, the EU also has a directive for the landfilling of waste: Directive 1999/31/EC (1999). This directive aims to prevent or reduce any negative impact that may originate from landfills on surface water, groundwater, soil, air, or human health. In order to achieve this, the directive has introduced strict technical requirements that landfills have to adhere to. Among these requirements is the call for the implementation of national strategies to progressively reduce the amount of biodegradable waste sent to landfills from all EU countries. Furthermore, the directive states that only waste that has been treated is allowed to be landfilled. Lastly, the operators of all landfill sites must apply and be granted a permit before being allowed to operate. This permit, among other things, must contain a description of the type and quantity of waste, the capacity of the site and a description of the site and operations, a description of the ways of preventing and reducing pollution of the environment, and details of closure and after-care procedures of the landfills. In 2018, in the same journal as the amendment on waste, an amendment on this directive for landfills was introduced. This Directive 2018/850 (2018) underpins the aim of the EU for a transition to a circular economy. This amendment introduces a ban on the landfilling of wastes that can be recycled or in other ways recovered from 2030 onwards. The directive also aims to limit the percentage of municipal waste that is landfilled to 10 per cent by 2035. The 2018 amendments make slight adjustments to the 2008 directives. They do not introduce any new, drastically different, or stricter rules and aims.

4.2.2 Netherlands

In paragraph 2.3.2 of the theoretical framework, Dutch policy was discussed. This sub-paragraph gives real-life examples of the theoretical concepts discussed here. From the interviews conducted for this research, three different roles of the government could be distinguished, which is the main institution of importance when it comes to waste-management in the Netherlands. The first role is formulating different regulations and policies concerning the management of mineral wastes and determining what the law is surrounding related practices. This responsibility also includes granting certain certificates for waste flows. The second distinguishable role of the government is the management of closed waste deposits. The third and last distinguishable role of the government is the commissioning of construction and demolition projects.

When dealing with wastes, it is important to have centralised regulations regarding the disposal and processing of those wastes, since they could contain substances harmful to people and nature. The governmental organ that is responsible for the rules and regulations regarding the management of mineral wastes is RWS, the executive agency of the ministry of infrastructure and water management. The main rules and regulations implemented are summarized in the National Waste Management Plan (LAP3). This is a published and publicly accessible law available online. The policy framework of the LAP3 elaborates in various chapters what the policy is with regard to waste prevention and management, together with the objective of the waste policy and definitions of terms used. In addition to policy, the LAP3 also has insight into various scenarios related to waste management, and the monitoring of waste policy. It should be noted that RWS is responsible for writing the policy but does not play a supervisory or enforcement role. In addition to the policy plan, the specific standards for all specific waste flows have been elaborated in the sector plans. These sector plans and policies describe how the waste must be stored, when it must be kept separate from other waste, and whether/when it may be mixed. Currently, RWS and other involved parties are working on a new version of the LAP3, called the Circular Materials Plan, which will introduce more laws and regulation to stimulate a circular economy:

> *"I was just talking about the national waste management plan, well we just finished version 1, 2 and 3, that has been around since 2000, and they are already writing version 4. But it is no longer national waste management plan, but the circular materials plan, and it's the same plan. But that does indicate that there is now a completely different perspective. The circular materials plan simply wants to have a different starting point from "how are we going to ensure that all our waste is properly processed" to more "how do we ensure that the circular economy takes shape""* (Translated by author) (Interview 1).

In addition to the rules from the Dutch government, Dutch waste producing and processing actors must also adhere to laws from the EU, as the Netherlands is an EU member and has agreed to these laws.

When looking at the practices of companies in the mineral and mass-waste sector, it makes sense that they adhere to the rules and regulations implemented by the government, as not adhering to them would be illegal. The Netherlands has a system in place to ensure that nearly all companies working with wastes are following legal routes. In the Netherlands, an environmental offence has been named an economic offence. This means that if one were caught committing an environmental crime, such as polluting the soil by illegally depositing contaminating substances, they are trialled as if they are suspected of committing an economic crime. This means that they are suspected of fraud, which gives them a criminal record, complicating all financial aspects of their life:

> *"In the Netherlands they have named an environmental offence an economic offence. And an economic offence, that immediately means a criminal trial"* (Translated by Author) (Interview 5).

Thus, Dutch companies involved with mass and mineral wastes are likely to adhering to the implemented rules and regulation. There is little chance they would admit to violating the rules publicly, however there is also no reason to suspect companies from not adhering to the rules as there is no proof of illegal activities. However, it is possible for the companies to do more than is expected of them, and in almost all cases this is what the companies are claiming to be doing. This behaviour does not come from a place of moral conscience though, as all the decisions towards more circular options within the construction sector are taken with economic advantages in mind:

> *"It is all economically driven. We're all in favour of a good environment and a sustainable society, also for the future, but it is and it remains a business and everything is economically driven. So, we don't do anything based on our feelings"* (Translated by Author) (Interview 4).

The simple truth is that often, circular options are cost-advantageous, in which case the company chooses the circular option, and sometimes they are more expensive than non-circular options. Within the limit of the law, the company will always choose the cheaper option.

It is this economic motivation that the government has taken advantage of, by putting quite a heavy levy on waste deposits. This way, recycling has become cheaper than putting waste in landfills, thus making companies choose the circular way. The tax that has been put on depositing wastes into landfills is 33,58 Euros per 1000 kg in 2022. This amount has gone up gradually, but the big change was between 2018 and 2019, when it went from 13,21 euros to 32,12 euros. (Belastingdienst, 2022):

> *"On everything you deposit, you lose € 33.58 before you start negotiating the deposit price and your transport, to force a circular solution. [...] You should actually make deposits so expensive that it pays to invest in the circular economy"* (Translated by Author) (Interview 3).

> *"And we know of the contaminated, non-applicable soil, and 95% of that goes to soil cleaners in the Netherlands. And why not to the landfill? Well, because in the Netherlands we simply levy very high taxes on landfill. We have a small country in the Netherlands, we don't have that much space for dumping, so we want that as little as possible. At the moment it is the case that I can have a soil cleaned for, well let's say € 40, € 45 per ton. But a landfill rate is € 60, € 70 per ton. And that's not because the landfill is so expensive, it simply has an environmental tax"* (Translated by Author) (Interview 6).

However, even though the Dutch government is trying to stop the depositing of wastes into landfills, a fraction of the wastes generated are not able to be recycled into the circular economy. This is the case for a number of toxic wastes and contaminated residues. In the interviews there were three substances that jumped out: sludge, asbestos, and per- and polyfluoroalkyl substances (PFAS). Sludge is the residue that is left after soil cleaning processes. This sludge is made up from all the contaminants that were washed out of the soil. This means it's a substance with highly concentrated contaminants that are harmful for the environment if it were to be reintroduced, resulting in the sludge having to be deposited:

> *"The machine actually splits the soil into relatively clean sand for reuse, and a sludge fraction that has to be dumped, approximately, 30/70, 25/75, and that sludge fraction is dumped"* (Translated by Author) (Interview 1).

The second substance, asbestos, was widely used in buildings, homes, and installations from 1945 to the 1980s, because of certain useful properties, namely that it is fire-resistant, strong, and cheap. However, when it was discovered that the substance poses a multitude of health problems, construction industries stopped using it. Despite this discovery, it is still present in many buildings stemming from that time. When construction and demolition projects take place on buildings from that time, and asbestos is one of the waste flows coming from the projects, it goes directly into landfills:

> *"We take in asbestos, but we can't do anything with it. That goes in a big bag to the landfill and is safely stored for the future"* (Translated by Author) (Interview 4).

Asbestos is what is considered a historical flow, which consists of materials that have been used in the past but not anymore, that are slowly becoming less and less until they are no longer in the system. The counterpart to historical flows is new process flows, which are new materials coming into the system.

One of these new process flows, are PFAS, which are synthetic compounds used in a variety of modern products. PFAS has the characteristic that it makes items water and oil-repelling, and because of this it found in water-resistant clothing, stain-resistant fabrics, and cookware. The problem with PFAS is that it does not break down organically, resulting in the nickname "forever chemicals". Furthermore, they travel and bind to water very easily. As such, PFAS have been detected in water, soils and even in humans. They are therefore a big problem for soil cleaners. Landfills have drainage to drain rainwater, as operational landfills are open on the top. PFAS can bind to this rainwater and travel down the drainage with the water into the environment. As PFAS are new compounds, and the knowledge that PFAS is present in the ground is even more recent. As such, there are no regulations yet for how much of the compound is allowed to be in, for example, clean soils. When a new or exotic compound does not have any regulations surrounding it, the amount allowed in soils is zero, which is strict. This means that unless soils with PFAS are completely cleaned, they have to be deposited, which also poses problems as the PFAS can seep out with rainwater:

> *"PFAS gets into your water, so the best available technique is extractive cleaning, because that's how you rinse the soil, so you remove those PFASs from the soil and put it in the water instead, but then you have it in your water. There were no standards for the drainage of your water, so we can clean the ground, but then we can't get rid of our water. Because it is an exotic, and there is no standard, the standard is zero, so the soil and water can't contain anything. Yes, that's very strict. You can't just filter it out of your water, that knowledge wasn't here yet either. We are now three years later, and we cleaned the first PFAS soil last December. [...] And luckily, we have a water-consuming process, so we use more water than we release, so those PFASs, they are continuously mixed into the process water. The best solution for pollution is delusion, right?*" (Translated by Author) (Interview 4).

Contaminants that are deposited in landfills can pose a huge risk for the environment and human health. For this reason, there are specific and strict laws in place that determine how landfills can and should operate. In addition to the LAP3, that describes waste management, there are two laws meant to protect the land and the environment from wastes and waste deposits: the law for soil protection (*Wet Bodembescherming*) and the law for environmental management (*Wet Milieubeheer*).

For operational landfills, the Landfill Decree (*Stortbesluit*) prescribes which facilities must be present at a landfill site in order to guarantee a certain level of protection for the surrounding environment and nature (Bodemrichtlijn, 2022a). When a landfill is operational, the landfill sites themselves are already separated from the surrounding environment. Before wastes are deposited, a double bottom seal made up of different kinds of watertight and airtight materials is placed at the bottom. This includes layers for the drainage of water. When this is in place, the landfill can be operational and wastes can be deposited there until it is full. When a compartment of the landfill is filled up, it is also sealed from the top using foils. While the closed landfill is completely sealed off, there is drainage for water and gasses that might get loose. The water is caught, cleaned in a water treatment plant before being released into the sewer system. The gasses can be used in the energy recovery process:

> *"The landfills in the Netherlands have a double bottom seal. That is with foil and drainage layers, so a double bottom seal, and then they are operational. When a compartment is full, it is also completely sealed at the top with foil and also with a double top seal. The leachate water that is released, because you are operational during a landfill, then of course it is completely open at the top, […] so from the rain that falls in you get leachate water and the leachate water is cleaned before it is discharged to the sewer"* (Translated by author) (Interview 2).

When a landfill is closed, the goal is to eventually be able to use the land where the former landfill was for new purposes. There is a specific project, 'aftercare for former landfills' (NAVOS), for tackling former landfill sites. The aim of the NAVOS project is to formulate feasible proposals for content, organisation, and financing of the aftercare of former landfills. In this project, the possible new purposes for the land are discussed, taking into consideration the contamination present in the land (Bodemrichtlijn, 2022a). Because the sites of former landfills are supposed to be repurposed, aftercare of these sites is needed because of the environmental risk they pose if not properly cared for. The contents of landfills are contaminated residues of the recycling process that could not be reintroduced into the circular system or wastes so contaminated that it was not financially feasible to clean them. Even though the wastes are sealed off by multiple layers, problems can still occur. These problems include groundwater problems, especially in the Netherlands since the groundwater levels in the Netherlands are relatively high; problems with landfill gasses, when they are not properly drained or caught; and problems with the top cover (Bodemrichtlijn, 2022b). It is for this reason that it is important that there are financial funds available for the aftercare of landfill sites, to prevent and tackle these problems. This way, it can be ensured that the contaminants do not seep back into the environment and the land can be repurposed in the best way possible.

This is where the second role of the government that was identified in the interviews comes into play. In addition to creating regulations and policies, the government is in charge of the management of closed waste deposits. The management of operational landfills is transferred to provincial care (depending on the province the landfill is located in) after closure of the landfill (Bodemrichtlijn, 2022c). It is stated in the law for soil protection that landfill operators have the obligation to provide a cost estimate and the manner of financial guarantee of the aftercare of the landfill while it is still operational. For closed landfills, this same obligation is stated in the law for environmental protection. During the time that the landfill was operational, the landfill operators have to build up a so-called target capital, which is the amount of money needed for the eternal financing of the aftercare. This amount covers both the regular aftercare and potential 'unwanted events'.

The third and last distinguishable role of the government is the commissioning of construction and demolition projects. The government in the Netherlands, whether that be national or regional, is responsible for some public buildings and, more importantly, public infrastructure. This means that for almost all infrastructure construction and demolition projects, the government is the one commissioning the project. In one of the interviews with KWS, a road construction and asphalt producing company, it was stated that about 80 per cent of infrastructure projects are government commissioned. However, this has no influence on the management of mineral and mass wastes, since the government is obligated to adhere to the same policies as companies:

> *"RWS sometimes generates waste itself when performing its duties as road manager, etc. RWS must then adhere to the same policy rules and legislation and regulations"* (Translated by Author) (Interview 7).

4.2.3 Norway

Norway is not a part of the EU and would typically not be obliged to keep to the agreed rules and regulations introduced by the EU. However, Norway is a part of the European Economic Area (EEA), an agreement which allows three members of the European Free Trade Association (EFTA) (Norway, Iceland, and Lichtenstein) to partake in the EU's markets using EU member state rules. In exchange, the EEA countries have to adhere to some regulations from the EU. In the EEA agreement, the earlier mentioned directives Directive 2008/98/EC (2008) and Directive 1999/31/EC (1999) were included, meaning Norway is obliged to follow the guidelines given in these directives. However, the 2018 amendments do not apply, as they are not included in the agreement.

As mentioned in paragraph 4.2.1, the directive for waste requires that 70 per cent of the waste from C&D activities must be recycled or prepared for reuse by 2020. In 2019, Norway's C&D waste recycling was at 52 per cent, meaning the country was not on track for attaining this goal set by the EU (Norwegian Environmental Agency, 2019). The EU target for household wastes was set for 50 per cent in 2020, but Norway was at 39 per cent in 2019 (Norwegian Environmental Agency, 2019).

As for laws and regulations set by the country's government itself, there are the Building Technical Regulations (TEK17), that all C&D projects must follow. TEK17 also includes chapters on waste, recycling, and circularity. The regulations state that the constructed object must be ensured a proper and intended lifetime so that the amount of waste over the construction's life cycle is limited to a minimum (TEK17, § 9-5). Furthermore, the products selected in a C&D project must be suitable for reuse and material recycling. Buildings must be designed and built in such a way that they can be dismantled, within a practical and financially sound framework (TEK17, § 9-5). The EU directive on waste requires all waste-producing companies to come up with a waste plan, and this obligation is also included in TEK17. The Norwegian regulations require that, for a given size of material, the owner of the material must have an environmental remediation description, a waste plan and a final report drawn up (Norwegian Environmental Agency, 2019). Furthermore, a minimum of 70 per cent by weight of the waste generated must be sorted on the construction site into clean wastes and delivered to an approved waste reception point, or used directly for recycling (Direktoratet for Byggkvalitet, 2022).

In addition to the technical regulations that C&D projects have to adhere to, Norway has implemented regulations on the recycling and treatment of waste (the waste regulations, or *avfallsforskriften*). In chapter 9 of the waste regulations, the regulations for landfills are given. These regulations state what kinds of waste are allowed to be landfilled; that all wastes must be processed before being landfilled; that landfills have to have a permit for operating, and the requirements for getting one are stated as well; and that all costs for construction and operation of a landfill must be covered by the price that the operator charges for depositing waste at the landfill (Lovdata.no, 2022a). The legally operating landfills report the amount of waste deposited into landfills annually, as well as the amount of used cover compounds and the residual capacity of the landfill to the pollution authorities in Norway (Norwegian Environmental Agency, 2019). In addition to regulations on waste depositing, the waste regulations also include regulations on the processing of all the different types of wastes, including mineral wastes. This law includes regulations on the treatment of mineral wastes by designated facilities, and to what these treatment companies have to adhere to. It also states conditions on the depositing of mineral wastes (Lovdata.no, 2022b).

However, despite the existing laws on mineral wastes disposal and landfills, and the targets for recycling and reuse set by the EU, there is still a large over-use of landfills for materials that could be introduced into the recycling and reuse system. Data shows that the landfilled amount of certain materials, such as concrete, have increased despite the call for a move toward a circular economy. Because of this, Norway, and more specifically the greater Oslo region, is dealing with decreasing landfill capacities and an increasing demand for the depositing of mineral resources. Based on reports of the pollution authorities the total capacity on landfills remaining in Norway was around 34 million m^3 in 2018 (Norwegian Environmental Agency, 2019). Of this amount, around 8 million m^3 is meant for industrial landfills. Data from this research shows that the decreasing capacity for landfilling is resulting in the search for alternative ways of disposing of wastes, and the search for new disposal sites in addition to the operational landfills. This means that in addition to legally operated landfills, the greater Oslo region is dealing with an increasing number of illegal or unofficial landfills, dealing within a black market of mineral wastes and sub-soil masses (soil, stones, etc.) (Sæther, 2022)[2]. These landfills are, for example, farmers for whom it is more profitable to rent out the land as a landfill than to cultivate the land for agricultural purposes. This takes place without permission from the local government or the surrounding inhabitants, and with the backing of wealthy waste-producing companies. The owners of such landfills charge around € 200 per truck load of non-polluted mineral wastes, which with the high number of truckloads full of wastes per year results in a very high income, while the operating costs of such landfills are low. Thus, profits are high (Sæther, 2022). Despite there being a framework and laws for wastes and landfills, the regulations and control are lacking, which enables these illegal practices to continue.

[2] Unpublished paper obtained through personal communication: Sæther, B. (2022). The urban-rural metabolic rift in sub-soil mass management: Practices in the Greater Oslo region. Oslo: University of Oslo.

4.3 Mineral Wastes and Circular Economies

The sub-question that will be answered in this paragraph is as follows:

> *How do the management practices of the mineral flows and deposits correspond to the current and future circularity aims of the involved parties?*

This paragraph discusses the state of the circular economy within the topic of mineral wastes. During the research, several barriers to accomplishing a circular economy were identified, which will be discussed in this paragraph. Furthermore, the changes that need to be made in order to achieve circularity will be discusses as well.

4.3.1 CE within the Mineral Wastes Sector

Throughout the research and as described in earlier paragraphs, both the governments of the Netherlands and Norway, and the EU as a whole, are striving towards implementing a more circular economy. As was described in paragraph 2.2 of the theoretical framework, there are four main approaches to implementing a circular economy: reduce, reuse, recycle, and recover. In the mineral waste sector, measures using all four approaches can be identified in both government policies and the approaches of waste-producing and processing companies. However, some are more common than others.

Reducing is a very common first measure implemented in the road toward circular economies, and in the waste sector. In both the Dutch LAP3 and the European directive on waste, the reduction (or prevention as both policies call it) of waste generated is central. The EU directive set up a hierarchy in what methods for waste management will be prioritized, and the first priority goes to prevention. The same mindset is seen in Dutch policies on waste, as they also state that waste prevention is the highest priority in the waste hierarchy (Figure 8, page 45). Waste prevention should take place within every step in an economic process, to end up with as little waste product as possible:

> *"The prevention of waste is one of the main targets of the waste policy. Waste prevention must take place in the whole economy, from the extraction of raw*

> *materials, the production process and distribution up to and including use and reuse"* (Translated by Author) (Rijkswaterstaat, 2022a[3])

However, while the Netherlands and the EU mention reduction as one of the main strategies, it is not mentioned as much in Norwegian policies. While Norway as a country is bound to the original directives on waste management and landfilling, and thus is bound to prioritise waste prevention in the waste hierarchy, the policies published by Norway do not seem focused on this strategy (Lovdata.no, 2022a; Lovdata.no, 2022b; Norwegian Environmental Agency, 2019). Instead, waste management plans seem to focus on the wastes already in the system.

However, policymakers are not the only party concerned with waste reduction. Operating companies also benefit from reducing their wastes. As stated earlier, companies' first priority is to gain economic advantages. Getting rid of waste is very expensive, especially considering the taxes that were introduced on landfilling in the Netherlands:

> *"That actually started many years ago to try to achieve that goal, or not try of course but to strive as much as possible to produce as little waste as possible, because that is actually very simply a very large cost factor so you want it that way keep it as small as possible"* (Translated by author) (Interview 2).

Therefore, by reducing waste, the companies are saving money on waste processing, which they are then able to use or invest elsewhere. Reducing is a method for circularity that is applied to the beginning of the chain, before waste is produced or put into the system. However, an economic system does not realistically function without the creation of waste products. For the waste that does get produced in the system, the three other methods for circularity can be deployed.

The second method of circularity is reusing, when a material is able to be reused in the state it was in when put into the waste system. This means that no additional processing has to take place in order for the product to be reused. Being able to reuse the material means that the material is not in fact waste, but a usable product that has ended up as a waste product. The EU

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[3] https://lap3.nl/beleidskader/deel-b-afvalbeheer/b2-preventie/

directive on waste defines reuse as *"Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived"* (Directive 2008/98/EC, 2008; p.10), however, this thesis finds that the last part of the definition is unnecessary. If the product or material is able to be reused in its original form, but for a different purpose than what it was intended for originally, it still meets the requirements for being a reused material, and thus circular.

Within the mineral sector, reuse already plays an important role. Specifically in the C&D sector, a number of materials is able to be reused. If materials are able to be separated on the building site, it is easier to reuse the materials, as they do not have to go into the waste-processing system first. When the materials are undamaged and uncontaminated, they can be reused, otherwise they have to be recycled. The materials are separated on site, so prevent contamination as much as possible:

> *"We try to separate as much as possible on the construction site.*
>
> [Interviewer:] *And that is done manually?*
>
> *Yes, by putting down six, seven containers. And what we want to achieve is that at the start of a construction project, a waste management plan is drawn up, so that people look at what waste is released in advance"* (Translated by Author) (Interview 6)

The third method for circularity is recycling. This method is the most used one from the three processing methods at the end of the waste-chain. Recycling is a central term in the EU directive on waste, where it is defined as *"any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes"* (Directive 2008/98/EC, 2008; p.10). The first paragraph of this chapter, paragraph 4.1, describes the ways in which the different kinds of mineral wastes can be recycled. As it has already been extensively discussed, there is no need to do it again now. Many of the policies made to promote a circular economy favour recycling methods over the other methods. Especially in the Netherlands, the infrastructure, technology, and machinery are already available in order to be able to recycle minerals on a large scale. From the numbers discussed in paragraph 4.1, it seems that the Netherlands does recycle most of the mineral wastes in the system.

One reason to choose recycling over reuse is that reusing requires materials that are undamaged and uncontaminated, while the recycling process uses everything. Furthermore, reuse requires the materials to be suitable to the reusing purpose, as by definition reusing does not include any additional processing. For example, it needs to have the right dimensions or the right strength/density. Reusing materials in new construction projects requires more planning than recycling materials does, as recycling delivers new materials in the exact requirements needed.

Recovery is the last approach to circularity. Recovery of waste means that waste materials are used to fulfil a useful purpose by replacing other (non-waste) materials that would have been used instead (Directive 2008/98/EC, 2008). The main waste-recovering practice is energy recovery, where waste materials are incinerated in order to create heat and energy. For this, materials such as wood are used, as it is easily burnable and contains a lot of energy. Other materials, such as stone, as not very suitable for energy recovery. Especially in the Netherlands, there is a very high capacity for incineration and energy recovery, which limits the amount of waste that is deposited.

> *"In the Netherlands, we have a high incineration plant capacity. Because of that, there is actually very little that goes into landfills. The majority can be incinerated and is incinerated. And the advantage of that is that energy recovery is able to take place. And with that, complete neighbourhoods are provided with district heating"* (Translated by Author) (Interview 6).

When a material is not able to be recovered, recycled, or reused, it goes to landfills. Landfilling is the final measure in waste processing and is only supposed to be used for materials that cannot be reused in the system in any way. In an ideal circular economy, there is no need for deposits as everything is able to be reused indefinitely. In this ideal scenario, the circle of the economy is closed, as nothing leaves it. However, in reality, this is not (yet) possible, and thus there is a need for landfills in order to able to be circular, as materials that cannot be reused have to be taken out of reusable materials.

Because of the shifting mindset towards circularity, the number of landfills has decreased, as policymakers are aiming for the reuse of materials instead of depositing. The Netherlands has 31 operational landfills at the moment (Rijkswaterstaat, 2022b). However, the majority is not for mineral wastes or contaminating wastes. The landfills that accept these wastes are limited and decreasing in number while no new ones are opened.

> *"For that* [deposit of mineral wastes], *we have a number of landfills in the Netherlands. I would say that there are about a dozen operational landfills"* (Translated by Author) (Interview 2).

In addition to the operational landfills, are closed landfills. These are covered up, or are in the process of being covered up, making the land available for new purposes. These new purposes consist of mostly recreational purposes, as the ground underneath the soil is heavily contaminated. Purposes that would require people to spend large amounts of time there such as housing or offices could pose a health risk. Nevertheless, there have been projects aiming to use old landfill sites for these purposes as well:

> *"There are also quite a few locations in the Netherlands where grass grows and maybe some sheep walk on them, but nothing else. There are also golf courses, we also have a ski slope nearby, [...]. We have recreational areas. Our office is actually the most progressive right now, but we are also working with a group, especially given the current housing shortage in the Netherlands, to see if we can put all kinds of tiny houses on those locations. You have to imagine that for residents there is a hurdle to overcome, living on a landfill, [...]. We think it is possible. And I think that the first projects will start soon. And that is the reason that we have built our office on the landfill, to show that we can work safely there and that there is no problem* [with the pollution] *at all. But I won't say the ground below is clean because it just isn't. We're sitting on heavily concentrated pollution"* (Translated by Author) (Interview 1).

For Norway, landfills play a much larger role than in the Netherlands. Where for the Netherlands, there are numbers available for the amount of (mineral) wastes that are landfilled, for Norway, there are not. However, it is known that a larger percentage of wastes goes into landfills. Norway does not have the same capacity for recycling and recovering wastes as the

Netherlands does, and thus a larger share is deposited. There is much improvement to be made here when looking at circularity, as a large part of the landfilled minerals could potentially be reused. There is no national information available on the number or location of landfills. However, in the greater Oslo region alone, there are 42 landfills (Sæther, 2022[4]). This number is larger than all of The Netherlands combined, which has 31 operational landfills (Rijkswaterstaat, 2022b), of which only about a dozen are open for mineral wastes. The large amount of deposited minerals and the number of existing landfills combined with the increasing number of illegal and unregistered landfills, poses a problem for Norway and its wish to be more circular.

4.3.2 Barriers to circular economies

Despite efforts from both policymakers and operating companies to implement a circular economy in the mineral-material sector, there are still barriers that prevent the implementation of true circularity. Within the interviews and data collected for this thesis, five distinct barriers to a circular economy were identified.

4.3.2 I Appreciation

The first barrier is appreciation. While often times there is the possibility for circular options, the appreciation of those option when compared to other ones is low. With countries moving more and more towards green and circular economies, there is more and more technology, infrastructure, and locations available to support such economies. This would allow, for example, C&D projects to be more sustainable. However, often times, the circular or green option is also the more expensive option. As mentioned before, the main driver behind the economy is money and not sustainability, the cheaper option is often the one chosen over the sustainable one:

> *"The appreciation for your solution by a client. And the client is often the government, so the government then asks, for example, to build a national road. Suppose you do it as circularly as possible with as little possible emissions, and it takes everything into account, then it costs a certain cost. Then there's someone*

[4] Unpublished paper obtained through personal communication: Sæther, B. (2022). The urban-rural metabolic rift in sub-soil mass management: Practices in the Greater Oslo region. Oslo: University of Oslo.

> *who does it cheaper but less green, and then the cheapest contractor still gets the work"* (Translated by Author) (Interview 2).

In addition to the appreciation from project clients, appreciation of the general public can also be a problem. The public is not always aware of the circularity of materials or projects, or they simply do not care. What the public cares about are safe, healthy, and aesthetically pleasing surroundings. While circular or green options are the more sustainable one, they are not always necessarily the aesthetically pleasing option. Furthermore, the public assumes. When they hear a certain circular material is re-won from waste materials, in some cases they assume that it is still waste and thus unsafe or unhealthy. This phenomenon is especially noticeable when looking at locals and their local environment. Most people are aware that circular options are more sustainable and agree that it is the better option, however when they are confronted with reclaimed waste items close to home, they change their attitudes:

> *"You have incinerator ash that meets all reuse standards in the Netherlands, but it does not look like beach sand as we know here in the Netherlands. The colour is a bit black; it has some glass since that's in the waste. Then if you put it underneath a road as a foundation, and people see that, they think, that looks like garbage. Well yes, it's not sand. And then you get protest groups here in the Netherlands, when that road will be close to their house, for example, and then they say "yes, but waste is used there!". Well, then a certain news channel will jump on that. And then that frustrates the reuse of cleaned products"* (Translated by Author) (Interview 2).

So, even when circularity through the use of circular mineral materials is a viable alternative for projects, appreciation by clients and by the general public can still be a barrier to actually choosing and implementing the circular option in projects.

4.3.2 II Gas & Electricity Prices

The second barrier for circularity within the mineral sector, is very recent and very specific to the timeframe of this thesis (January - October 2022). Namely, the prices for gas and energy are extremely high compared to before. Energy suppliers purchase their gas and electricity on a European stock exchange. How much they pay for gas and electricity is a matter of supply and demand. The prices have gone up significantly in 2022, mostly due to the situation involving Russia. After Russia unlawfully invaded Ukraine in February, the majority of the

European countries, including the Netherlands and Norway, spoke out against Russia, and sanctions were taken against Russia. In response, Russia limited its gas export to Europe, increasing the demand for gas significantly, resulting in an increase in price.

This is a barrier for circularity in the mineral sector, since many recycling and recovering methods for mineral wastes depend on gas. For example, the thermal cleaning of soil uses almost exclusively gas. These high prices have resulted in increased running costs, to the point where it is hardly profitable or justifiable to recycle or recover anymore:

> *And the price is € 335 per megawatt hour as of today* [07/03/2022]. *Then it is better to shut down your installation. This is now also happening in the Netherlands. One thermal installation has already been shut down because natural gas prices are simply too high."* (Translated by Author) (Interview 3).

After the interviews were conducted in March of 2022, the price has only gone up more. It is not yet known if and when the prices will return to previous levels.

4.3.2 III Un-circularity in beginning of chain.

This thesis so far has been about circularity at end of the production chain, and how circularity is and can be implemented for waste materials. Circularity, however, is implemented at both the end and at the beginning of the production chain. It is therefore important to also look at the beginning of the chain when discussing the end-of-chain processing. If materials are introduced there that are easily separated from other materials and that are recyclable, circularity is quite an easy and obvious option. However, materials that are not circular at all are still being introduced into the system on a large scale, which poses problem for the possibility of a circular economy:

> *"There are all kinds of products that the government still allows to be put on the market, and people use and buy those items that, if you really think about it, you already know there's no possibility to make them circular. And I think that's the worst part. […] We have the current system, in which it is just way too easy to make products that are not recyclable"* (Translated by Author) (Interview 6).

Circularity is a phenomenon that needs to be implemented at all stages of the production and consumption process of a certain material or item. The waste sector can only do so much for the circular economy if circularity is not planned for in earlier stages.

4.3.2 IV Policy

The main barrier to a circular economy within the mineral sector, is policy. While there have been several policies introduced to promote circularity, as discussed in paragraph 4.2, it is still lacking in a lot of areas, allowing non-circular practices to continue.

While policy has been written and implemented, the problem often lies with the enforcement of policy rules. Within the Netherlands, there is a system in place that makes many of the policies not legally binding. Instead, they are an agreement between different parties. Furthermore, there can be a regulatory gap between national policy, provincial policy, and municipal policy, which leaves certain rules and laws up to interpretation and leads to differences between areas within the same country. So, while Dutch waste producers and processers agree that the laws in the Netherlands for mineral wastes are good overall, they are still lacking in areas, which is allowing non-circular practices to take place:

> *"The hindering factor is the regulations for those residual flows* […] *The various governments do not talk to each other and they do not ensure there is an integrated part, meaning that when they impose something, that we are ALL able to pass or fail"* (Translated by Author) (Interview 4).

> *"But one of the problems we have is the interpretation of legislation. There is a difference between local legislations. Because the legislation and standards are not really set in stone, you can, for example, use certain soil in one area and not in another area. And that's something that throws up a barrier. […] Because strict legislation means, okay, the traffic light is red, you are not allowed to keep driving. But with us the traffic light is vaguely orange, and then you can choose whether you brake, or whether you keep driving"* (Translated by Author) (Interview 5).

As for the lack of circularity in Norway, that can also be blamed on policy. There is a need for more landfilling capacity. However, the legal process regarding the opening of new landfills is slow and complicated. On the one hand, it is a problem of legal complexity, where there are many different policy levels that need to cooperate, which takes time and effort. Furthermore, the regulations that are in place for mass mineral wastes have not been developed to promote circular solutions. On the other hand, in the legal process, not all legal requirements are always met, meaning more time is spent on fixing these wrongs (i.e., not informing neighbours about new landfill plans or not being truthful on environmental risk assessments). Furthermore, supervisory and enforcing actors are lacking, allowing illegal practices to happen and continue. Norway is very focused on a green economy and sustainable practices, however, the focus on this goes almost entirely towards reducing greenhouse gas emissions. Other sustainability subjects, such as waste processing, get little attention (personal communication, April 25th, 2022).

4.3.2 V Landfill Capacity

As mentioned earlier, landfills that accept the residues of mineral wastes recycling are limited and decreasing in number, and at the same time no new ones are opening. This is done in an attempt to promote circularity, with the mindset that if less materials can be deposited, more materials have to be recycled. However, this is working counterproductively. Currently, it is not possible to put 100 per cent of the materials that are put into the system back into the system. This need for landfill capacity also corresponds to the first limit of circular economies from the theoretical framework (2.2.2), namely thermodynamic limits (Korhonen, Honkasalo & Seppälä, 2018). In a growing economic system, such as the Netherlands, the generation of waste, loss of energy and materials and use of new materials is inevitable, as the technologies to avoid this have not been invented and perfected yet. This means there is still a need for landfilling. Thus, the processing of mineral wastes also produces unavoidable residue. This residue needs a place to go too, which is not something policymakers always keep in mind:

> *"I am also explaining to the government that if we move towards that circular economy, that could also mean that new flows will go to landfills, that you should not say "okay we won't have any more need for the landfills", yes eventually you will no longer need them at all in 2050 or something, but until then you will, it is important that you maintain that, and that you take the residues that cannot participate in a circular economy, that you take out them out, and that they get a good place* (Translated by Author) (Interview 1).

In Norway, and more specifically the greater Oslo region, the need for more landfill capacity is also noticeable. Norway has a significantly lower recycling percentage of mineral masses than the Netherlands. Although Norway has more operational landfills, they also have more materials going into landfills, to the point where the legally operated landfills cannot keep up. The regulatory process for opening new landfills is slow, but because the demand for landfilling is high, illegal landfills appear.

There is a current need for landfills and for the foreseeable future there will be a need for landfills. If all landfill capacity is filled up, the recycling of mineral materials will be complicated since the residues of that recycling process will have no place to go. One option is that the wastes end up being exported to poorer countries with worse policies for circularity and waste management. This might solve the waste-problem locally but will increase it globally.

4.3.3 Future needs

When looking at the global economy, the world consumes about 100 billion tonnes of resources every year. Of this amount, only 8,6 per cent is cycled back into the economic system, which means over 90 per cent of the resources end up as waste (Circle Economy, 2022a). The Netherlands is doing significantly better than this global average. The percentage of resources used in the Dutch economy that are cycled back into the system is 24,5 per cent (Circle Economy, 2022b). The Netherlands is among the best globally with this percentage. Norway, on the other hand, has a circularity percentage of only 2,4 per cent, which is well below the global average (Circle Economy, 2022c). This, combined with the fact that Norway is among one of the countries with the highest rate of consumption at 44,2 tonnes per person per year, is worrying for the circularity aims of the country. These numbers, however, are on circularity as a whole, including all wastes. For C&D waste materials specifically, the Dutch percentage lies at about 95 per cent (Zhang et al., 2019). This is well above the EU target of 70 per cent minimum. Compare this to Norway’s 52 per cent (Norwegian Environmental Agency, 2019), and it becomes quite clear that the Netherlands is farther along its circularity journey than Norway is.

Thus, the Netherlands is a frontrunner when it comes to a circular economy, specifically when looking at mineral masses. This can be attributed to several reasons. The first reason is simply that the Netherlands is a small but densely populated country. The current population is 17.6 million people (CBS, 2022), while the size of the country is 42,000 km^2 (CBS, 2020). This means that the density of the population is about 510 inhabitants per km^2, which makes it one of the most densely populated countries in Europe. About half of this land is used for agriculture, and only about 13 per cent is used for the built environment. The remaining area is mostly taken up by bodies of water, and some forest and nature. This means that unused land is quite scarce and needs to be utilised efficiently. There is little space available for landfills. Thus, much of the waste is recycled instead of landfilled:

> *"I believe that also has to do with the fact that the Netherlands is much smaller, so we live much closer to each other, space is scarce so you have to deal with that well. Everyone realizes that. Governments realize that, but even private individuals are of course also aware of this."* (Translated by Author) (Interview 2).

In addition to scarcity, another factor that determines the limited land-uses is the fact that most of the Netherlands is either below sea level or right above it, and the main source of drinking water is groundwater. This means that the contamination of drinking water is a big risk if land use is not regulated heavily, since groundwater is not very far below the ground anywhere in the country. Norway on the other hand, has 5.5 million inhabitants on a 364,266 km^2 area. This means that Norway has a population density of about 15 inhabitants per km^2. While the terrain in Norway consists of more unusable areas such as high mountains, the total unused usable space of the country is much higher than in the Netherlands. Norway does not have the same space concerns as the Netherlands does, which might contribute to the disparity between the countries.

A second reason that was given for the Netherlands being a frontrunner, is material scarcity. The Netherlands is a river delta, and because of this geography of the country, there is a scarcity of certain mineral masses. The soil of the country is almost entirely made up out of sand and clay or sedimentary soils. There is no rock, gravel, or other non-sedimentary soils. When these scarce materials are, for example, used in construction projects, they need to be imported from countries that do have them, like Norway. This is expensive, so recycling and reuse of mineral masses can be an economic advantage:

> *"We* [the Netherlands] *have a lot of sand, a lot of sand is extracted from the sea, so that is a source that we do have. But everything in terms of gravel flows, we have no gravel and no granite. Granite is of course used for asphalt, which comes from Norway for example. So, if you break up an old asphalt road, then you actually want to reuse that gravel because otherwise you have to get it from Norway again. So, in the Netherlands that is the realization, that we have to be frugal with it.*" (Translated by Author) (Interview 2).

A last reason given, is that the Netherlands already has the required infrastructure and technology available for the processing and recycling of waste. The reason was discussed in Dutch Policy of the theoretical framework. In the 1990's, the Netherlands realised there was limited space available, and that space should not be used for landfilling. At this point, a lot was invested into the construction of mainly incinerator installations, but also other recycling plants, in order to bring down the amount of landfilled material (Savini, 2019). Presently, the Netherlands has a high capacity for incineration, which is more than the country needs. Waste is imported from neighbouring countries because there is capacity for it:

> *"We have by far the highest percentage of incineration in the Netherlands. Well, that all happened in the nineties, they said we have to stop landfilling and it should all be incinerated, that which is able to be incinerated of course, but you see that incinerating waste also comes with all kinds of problems"* (Translated by Author) (Interview 1).

This infrastructure is not available in Norway. In order to achieve a more circular economy, a lot needs to be invested into building the needed structures and installations for waste processing and recycling. This is a barrier for Norway achieving circularity, corresponding to one of the limitations of a circular economy discussed in the Limitations to CE, namely path dependency (Korhonen, Honkasalo & Seppälä, 2018). Implementing circularity into an existing system is more difficult than it sounds because the current technologies are not easy to replace.

The Netherlands is already doing pretty good on the circularity front. The main problems hindering a further move forward are the problems mentioned earlier, which could be resolved through a more open dialogue between waste producers and processers, and policymakers, so that policies, including tax, landfill capacities, and circularity measures at the beginning of the chain, can align better with the circularity goals. The problems of high gas prices and appreciation of circular options seem to be problems that need time to resolve itself and cannot just be resolved instantly. Norway, on the other hand, is not doing so well when it comes to circularity. However, there are several measures that can be taken by the country, and on lower scales like the greater Oslo region, that could stimulate a more circular economy in the mineral masses sector.

One of the main problems that lead to the large amount of deposited mineral masses, is that infrastructure and construction projects often lead to a large surplus of unused mineral materials (Bygballe, Flygansvær, Harrison & Soldal, 2021). This surplus consists of uncontaminated and reusable materials like stone and soil, which could easily be cycled back into other projects. However, these materials are often landfilled. Instead, new raw materials are extracted and used. In order to fix this problem, two things should happen. Firstly, before the start of a new project, a comprehensive list should be made about what materials will be used in what quantity, in order to avoid large surpluses of unused materials. Second, surplus materials need to be managed better. Uncontaminated and usable materials should be separated and reused, and only unusable materials should be disposed of. While there are little facilities in the country that can process mineral wastes into recycled mineral or recovered energy, there is the ability to reduce and reuse. In time, there need to be investments into recycling and recovery options too, however reducing, and reusing waste is already achievable and should be prioritized.

Furthermore, another problem that is causing the mineral mass problems in Norway and its regions, is bad policy. The country simply lacks the policies to enforce good circular practices. The extreme bureaucracy is hindering the implementation of solutions and clear and good legal processes are hard to achieve. There needs to be better communication between different levels and branches of governments, as well as between local peoples and communities. Furthermore, there needs to be more control and enforcement from government authorities, in order for illegal practices such as illegal landfills to stop. This means more need for coordination of mineral mass materials, better regulations, and better planning (Norwegian Environmental Agency, 2021).

A last problem concerning Norwegian mineral masses, is that there is little to no data available on the exact volumes of used and deposited materials. It is nearly impossible for researchers to get access to such data, as all parties are very secretive about it and would rather avoid the subject. An open dialogue and public information could lead to more awareness of the problem that the extreme landfilling of mineral masses pose, which could lead to more parties looking for a solution.

5. Discussion

Now that the three sub-questions have been discussed, and the results from the research of this thesis have been given, it is possible to aim at answering the main question of this thesis. The discussion, this paragraph, is dedicated to the main research question. This paragraph will be built up as follows. The first sub-paragraph will focus on answering the main research question. This will be done through interpreting the results of this research, which was discussed in the empirical background in chapter 4, where each sub-question of this research was discussed separately. The second sub-paragraph will discuss the limits of this research, and difficulties encountered throughout, that may have hindered the research. The third paragraph will give recommendations for future research related to the subject.

5.1 Answering the Main Research Question

The main research question of this Thesis is:

What is the status of the management of mineral mass flows and deposits in the Netherlands?

This question is supplemented by a secondary research question, namely:

How does the status of the Netherlands stand in context to Norway, and how and why has the difference between the countries come to be?

The aim of this question is to identify what the state of the management of mineral mass flows and deposits is in the Netherlands, and to put that into context to Norway. The research questions can be divided into three different parts: describing the state of the management of mineral mass flows and deposits in the Netherlands; describing the same for Norway and providing context for the former; and explaining where the difference between the two could be coming from.

The first sub-question was: "*What do the stocks and flows within the system of mineral management consist of and what does the exchange within the system look like?*". This question was discussed in paragraph 4.1, where a comprehensive overview was given over the different kinds of mineral materials in the system, and how they are generally processed and disposed of. From the numbers discussed in the chapter, it is apparent that the majority of mineral wastes are recycled in the Netherlands, and only a fraction ends up in landfills. For Norway, there is little data available, and for certain mineral flows there is no data at all. There is data on the amounts of wastes of certain materials, but there is no data on how much of it is recycled and landfilled. However, from interview data, it seems that the recycling rate is much lower than the Netherlands, with much more usable mineral materials ending up in landfills.

The second sub-question was: *"What are the regulations and practices in place surrounding the management of mass-flows and mass-deposits?"*, discussed in paragraph 4.2. There are policies on waste management and landfilling on different government levels. The highest level is the EU, which implemented directives in 2008, that both the Netherlands and Norway have to adhere to, and additional directives in 2018, that are not binding for Norway but they are for the Netherlands. These EU directives set targets for reuse and recycling percentages and determines rules for landfilling practices. Furthermore, there are national policies on waste management and landfilling. The policies and laws in the Netherlands are quite strict and quite advanced, when compared to the EU policies and Norwegian policies. This results in a comparatively high recycling and low landfilling rate, making the Netherlands a frontrunner when it comes to mineral waste. There are strict limits on landfilling and financial motivators for recycling instead of landfilling. Furthermore, there is an openness over the data on mineral wastes, and strict laws on reporting data, which makes it easier to determine (the lack of) illegal practices taking place in the country. Norway also has laws in place on waste management, waste processing and landfilling. However, these laws are less strict than the Dutch laws are. One major difference in policy is that there is no landfill tax in Norway, while there is quite a high one in the Netherlands. While there are laws and policies in Norway from both national and European governments, the recycling rate is not high and there is a large over-use of landfills for materials that could be introduced into the recycling and reuse system. Furthermore, there is a huge lack of data on waste processing in general, which makes it difficult to research, but it also makes it difficult for governments to see the practices taking place, and the wants and needs in potential circular mineral waste policies.

The third and last sub-question was: "*How do the management practices of the mineral flows and deposits correspond to the current and future circularity aims of the involved parties?"*, discussed in paragraph 4.3.The shift towards a circular economy is currently one of the most important goals in the mineral mass sector. In all policies currently made and implemented, the goal for circularity is central. There have already been important developments for the implementation of circularity, such as policies promoting it and recycling techniques becoming available. However, despite policy and technology being available, there are still certain barriers to circular economies. The main barriers identified in the collected data were: a lack of appreciation for circular solutions and circular options; the currently skyrocketing prices for gas and electricity; the declining landfill capacity because of the governments push towards recycling; lacking or counterproductive policy; and, related to the policy problem, a high and increasing tax on materials going into landfills. In the Netherlands, even though the country is doing pretty well, the main measure that should be taken is policy related. There needs to be more dialogue between policymakers and mineral waste producers and processers, so the needs and goals of both align better. Norway, however, is doing less well, and needs to take more measure to reach a circular mineral economy. In addition to better policy, which is severely lacking and allowing un-circular and even illegal landfilling practices to take place, there needs to be more investments in waste recycling and recovering facilities, as there are not many facilities available for mineral recycling. However, this will take time. In the meantime, focussing on recycling and reuse should be a priority, as this is already possible.

After discussing the three sub-questions, there is a clearer overview of the state of mineral mass waste management in both the Netherlands and Norway. Furthermore, some explanation has been found for the difference between the two countries. This thus makes it possible to give an answer to the main question posed in the thesis, since these two things were the main aims.

The Netherlands is quite far along on the road towards (mineral) circularity, compared to other countries. The first reason is geography. The Netherlands is a small but densely populated country, which means that unused land is quite scarce and needs to be utilised efficiently. There is little space available for landfills. Thus, much of the waste is recycled instead of landfilled. In addition to scarcity, another factor that determines the limited land-uses is the fact that most of the Netherlands is either below sea level or right above it, and the main source of drinking water is groundwater. Thus, contamination of drinking water is a big risk if land use is not regulated, since groundwater is near the surface. This differs from the geography of Norway, which is much larger and less densely populated, making landfilling a more common option because of the available space, Furthermore, Norway has a lot of height difference, it is not flat like the Netherlands. It is also not close to sea level in most of its area. Much of the drinking water comes from surface waters, instead of groundwater, so soil and groundwater contamination are not as much of an issue. Surface water contamination, however, is, and there are heavy regulations surrounding the contamination of drinking water sources such as lakes. A second reason that was given, is that the Netherlands is not very rich in mineral materials, such as rock and gravel. Because of the geography of the country, the soil of the country is almost entirely made up out of sand and clay, or sedimentary soils. When mineral materials that are not native to the country are needed in construction projects, they need to be imported. This is expensive, it can be an economic advantage to use recycled mineral masses. Norway does not experience this same mineral shortage, as the country is rich in materials such as rock and wood, as large parts of the country are mountainous and forested. A third reason given, is that the Netherlands already has the required infrastructure and technology available for the processing and recycling of waste. The country has already invested a lot into waste processing and recycling facilities in the past, allowing for a much smaller flow into landfills. Norway does not have this existing infrastructure, and in order to reach the same level of circularity of the Netherlands, a lot needs to be invested into such facilities.

However, the main reason that seems to determine the difference between the two countries, is policy. Even though the policy in the Netherlands is not perfect and several shortcoming have been identified, it does allow for a relatively high percentage of circularity, compared to other countries. Policy in the Netherlands is made using the polder model, discussed in paragraph 2.3.2. The current and future policies discussed in paragraph 4.2 were also made using this model. This model allows for policies that are suited to stakeholders involved and bridging the gap between what is desirable and what is possible. Dutch policies on circular economies and waste processing have been implemented since the end of the 20th century, when the problems with waste became apparent. This has led to investments in waste processing technologies and infrastructures from early on. Norway does not have the political polder model, meaning there is a gap between the policies implemented currently, circularity aims, and the wants and needs of mineral waste processors and producers. Norway also has not invested early on in the processing of waste. Furthermore, Norway lacks the policies to implement and enforce good circular practices. The extreme bureaucracy is hindering the implementation of solutions and clear and good legal processes are hard to achieve. There needs to be better communication between different levels and branches of governments, as well as between local peoples and communities. Additionally, there needs to be more control and enforcement from government authorities. This means more need for coordination of mineral mass materials, better regulations, and better planning.

A last difference between the Netherlands and Norway is the availability of data. In the Netherlands, all data on mineral wastes, recycling and landfilling are publicly available to anyone who needs them. This ensures a level of control, as all waste processing actions are visible and accounted for. For Norway, there is little to no data available on the exact volumes of used and deposited materials, and it is nearly impossible for anyone to get access to such data. This means there is no overview over what practices take place exactly, accountability is low, and there are opportunities for illegal practices, since no-one can trace it back in the system. Openly available data and information could lead to more awareness of the problem that the extreme landfilling of mineral masses pose, which could lead to more parties looking for a solution.

5.2 Limitations of the Research

Although it was insured in the preparation phases of this thesis research that the research would be conducted in the best and most reliable way possible, there were still several limitations of the research and study done that need to be acknowledged. These limitations do not take away from the quality of the research, but not having had these limitations might have enhanced it.

The first limitation that needs to be acknowledged, is the method by which the interviews in the research study were held. These interviews were held online instead of in-person, which meant that an essential element of in-person communication was lost. Ideally, these interviews would have been held in-person, so that elements such as body language and communication dynamics would have played a larger role in the interviews. While there was no suitable alternative to online interviews due to the ongoing COVID-19 crisis and regulations, it did limit the data from the study.

Furthermore, the sample size of the study consisted of six oral interviews, one written interview, and interview data obtained through the supervisor of this thesis, who is also working on the same subject in his own research. Additionally, data obtained online and in databases was used. Even though the amount of obtained data was sufficient for conducting the research and answering the research questions given, the study would have benefitted from a larger sample size, as there would have been more data available, which would have increased the reliability. This hold especially true for the Norway part of the study, as there was no data collected for Norway by the researcher herself, apart from data available online and in other research papers.

However, this is related to the third limitation of this research. Namely, the lack of data available and obtainable about the Norwegian management of mineral masses. The lack of data from the Norway side of the study did not come from a lack of trying, but from a level of secrecy surrounding the subjects. As mentioned earlier, there is no data available on the amounts and kinds of mineral wastes that are deposited and recycled in Norway. Furthermore, it is difficult and nearly impossible to talk to related actors about the subject, as these actors are unwilling to release information. Thus, the researcher was unable to gather data from the actors in Norway. However, the researchers supervisor was able to obtain data and some information on the subject by talking to some actors and for this reason this data was used in this research as well. Nevertheless, more openness on the information and data from Norwegian actors would have significantly helped this research, and results might have been more defined.

5.3 Further research

This research has contributed to the existing research on mineral wastes, waste management, and mineral wastes depositing, by providing an overview on the existing situation in two countries, as well as the EU. While there has been research on mineral wastes in the past, it is still quite an unexplored subject in the waste literature. Furthermore, this study has provided an analysis of one country while putting it into context with another, providing additional clarity on the actual situation. The results of this research could contribute to finding more circular solutions for mineral wastes, by identifying where circularity is lacking and what the barriers to achieving circularity are. The study has also revealed a significant knowledge gap in the research on mineral wastes in Norway specifically. While there has been previous research on the management of mineral masses, it is still a relatively new subject, especially put into the context of circular economies. It could benefit from more research.

First and foremost, more research needs to be done on the management of mineral masses in Norway. Furthermore, more data is needed on the recycling and depositing of mineral masses. Specifically deposits and illegal deposits seem to pose a significant problem in the landscape. More data needs to be collected, and more data needs to become publicly available, in order to get a comprehensive grasp on the actual situation in the country. While it can be deduced that the circularity in the country is lacking, as has been done in previous research, actual comprehensive data, with which not only the situation can be reviewed, but also solutions for a more circular economy could be investigated and recommended, is needed.

Furthermore, there needs to be more research into the recycling and depositing of new products and materials that currently pose a problem in the circular recycling process. For example, PFAS and batteries pose a big problem, rendering soils and ashes contaminated with these materials useless and condemning them to landfills. In order to achieve a circular mineral sector, it is important that unrecyclable materials such as these should be either taken out of the system, or a method should be found in order to process them. Research on the subject could contribute to such solutions.

6. Conclusion

The main research question of this Thesis was:

What is the status of the management of mineral mass flows and deposits in the Netherlands?

This question is supplemented by a secondary research question, namely:

How does the status of the Netherlands stand in context to Norway, and how and why has the difference between the countries come to be?

The aim of this thesis was to uncover the differences in the management of mineral stocks and flows, putting the situation in the Netherlands into context with Norway. The outcomes of this research show that the state of mineral circularity in the Netherlands is generally good. The Netherlands seems to be a frontrunner when it comes to mineral waste recycling and the landfilling rates are low. Norway, however, is not as circular. A lack of data on the subjects makes it difficult to precisely say something on the current state, but it is apparent from the data that that the recycling rate is much lower than the Netherlands, and much more usable mineral materials end up in landfills. As for the latter part of the question, *"how and why has the difference between the two countries come to be?*", there are several things that could explain the difference.

The first reason is geography. The Netherlands is a small and dense country, leaving little space suitable and available for landfilling. Furthermore, there is a risk of groundwater contamination because of the flat, delta geography of the country. Groundwater is the source for drinking water, so landfilling poses a contamination risk that needs to be contained. Norway has a whole different geography. It is large, sparsely populated, and mountainous. For this reason, the threat of landfills is not as large, and there is less incentive, from a geographical standpoint, for recycling instead of landfilling. The second reason is also related to geography, which is that the Netherlands does not have the same mineral reserves as Norway does. The Netherlands mainly consists of sedimentary minerals. Construction materials such as stone, gravel and wood thus need to be imported, which is expensive. Recycling is therefore an economically advantageous option as well. Norway has a large reserve of rock and wood, and thus does not face the same problems. A third and last reason given, is that the Netherlands already has the required infrastructure and technology available for the processing and recycling of waste, since a lot of money was invested in waste management projects in the past. Norway does not have this existing infrastructure, and in order to reach the same level of circularity of the Netherlands, a lot of money needs to be invested into such facilities.

However, the main reason that seems to determine the difference between the two countries, is policy. Even though the policy in the Netherlands is not perfect and several shortcoming have been identified, it does allow for a relatively high percentage of circularity, compared to other countries. For Norway, there is a gap between the currently implemented policies, circularity aims, and the wants and needs of mineral waste processors and producers. Furthermore, Norway lacks the policies to enforce good circular practices. The extreme bureaucracy is hindering the implementation of solutions and clear and good legal processes are hard to achieve. There needs to be better communication between actors. Furthermore, there needs to be more control and enforcement from government authorities. This means more need for coordination of mineral mass materials, better regulations, and better planning.

The shift of the mineral sector towards a circular economy is currently one of the most important goals within the sector. Circularity is a central term within decision-making processes and policy decisions, from all actors in the system. This thesis has contributed to the existing research on mineral wastes, waste management and deposits, by providing an overview on the current circularity situation in two countries. From a practical perspective, this thesis has highlighted the problem areas when it comes to implementing a more circular mineral economy. These problem areas could be taken into consideration when writing, for example, policy for implementing circularity in relevant sectors. The results of this research could contribute to finding more circular solutions for mineral wastes, by identifying where circularity is lacking and what the barriers to achieving circularity are.

There are also a number of theoretical learning points from this thesis. The purpose of the concept urban metabolism in this thesis was to aid in assessing the flows of materials and energy throughout an urban area, in order to give information about, among other things, the status of material cycling and waste management in urban systems of the Netherlands and Norway (Kennedy, Pincetl and Bunje, 2011). This thesis has given a comprehensive overview of this, and so added to the urban metabolism theory and literature by putting the theoretical concepts into a practical case.

Furthermore, the results of this thesis research have shown the importance of enlightened policy making over a long time span. The Netherlands has worked on implementing circularity in the mineral sector since the 80’s (Savini, 2019), which has resulted in a fairly circular mineral economy forty years later. Furthermore, the policies have been made in consultation with relevant actors as according to the polder model (Cruijssen, 2020), resulting in fitting policies.

Lastly, the theoretical chapter has given an overview of the general known limits to a circular economy (Korhonen, Honkasalo & Seppälä, 2018). This thesis has confirmed and expanded to some of these limits, by showing what the theoretical limits of thermodynamic limits and path dependency look like in practice and not just in theory. The Netherlands has invested a large number of years into achieving a circular economy through policy and infrastructure, resulting in the country being a frontrunner when it comes to circularity in the mineral sector. This also makes the case of the Netherlands a good case for this research. However, the case is not easy to replicate in other countries such as Norway, mainly because of the path dependency limit. Norway does not have the same investments into circularity as the Netherlands, and it will take a number of years and investments to achieve a similar level of circularity. The study has also revealed a significant knowledge gap in the research on mineral wastes in Norway specifically. However, finding the problem areas is a start, because only by knowing where one is on the journey to circularity, can one know what the next step to take is.

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Appendix I
Interview Guides

Table 4: Interview guide for waste companies

Themes	Items	Questions	
Introduction	Personal information	Could you tell me a little about yourself?	
	Employment and function	What company do you work for and what does the company do?	
		What is your function within the company?	
Urban metabolism	inputs	How much new wastes does the company receive and process?	
	outputs	How much of the waste is recycled and how much is stored?	
		Where and how is it recycled?	
	Storage	Where and how is it stored?	
		How much waste is currently in storage landfills owned by the company?	
Circular economies	reduce, reuse, recycle and recover	Are you familiar with the concept of a circular economy?	
		Is your company interested in moving towards one?	If yes, how?
			If no, why not?
		What is your company doing to reach this? Reduce, reuse, recycle or recover?	
	scale	On what scale is the company looking at circularity for? Regional/national/global?	
	Challenges	What are the challenges for moving towards a circular economy	For this company?
			For this sector in general?
Regulations & Practice	Regulations	Which regulations from government bodies does your company have to follow? Which are most impactful?	
		Are there any changes in the regulations recently or in the near future that have impacted your practices?	
	Practice	Do the practices align with the regulations? Do you do more/less?	
		How much do other companies within this sector follow the regulations in general?	
Conclusion	Opinion	What is your opinion on the current state of mass-flows and waste in the Netherlands?	If yes: why and how?

Table 5: Interview guide for construction/dredging companies

Themes	Items	Questions	
Introduction	Personal information	Could you tell me a little about yourself?	
	Employment and function	What company do you work for and what does the company do?	
		What is your function within the company?	
Urban metabolism	inputs	How big are the flows within the company and wat do they mostly consist of?	
	outputs	How much new wastes does the company create?	
		How much of the waste is recycled and how much is stored?	
	Storage	Where and how is it recycled?	
		Where and how is it stored?	
Circular economies	reduce, reuse, recycle and recover	Are you familiar with the concept of a circular economy?	
		Is your company interested in moving towards one?	If yes, how?
			If no, why not?
		What is your company doing to reach this? Reduce, reuse, recycle or recover?	
	scale	On what scale is the company looking at circularity for? Regional/national/global?	
	Challenges	What are the challenges for moving towards a circular economy	For this company?
			For this sector in general?
Regulations & Practice	Regulations	Which regulations from government bodies does your company have to follow? Which are most impactful?	
		Are there any changes in the regulations recently or in the near future that have impacted your practices?	
	Practice	Do the practices align with the regulations? Do you do more/less?	
		How much do other companies within this sector follow the regulations in general?	
Conclusion	Opinion	What is your opinion on the current state of mass-flows and waste in the Netherlands?	If yes: why and how?

Appendix I -2
Written interview questions (Translated)

The management of mineral flows and waste and the transition to a circular economy
Written Interview

Questions about mineral flows and waste generation and processing:

- How large are the mineral flows and mineral waste flows in the Netherlands, and what do these flows mainly consist of?
- What proportion of this is recycled and what proportion is landfilled?
- Where and how is it stored and how does Rijkswaterstaat ensure that this is done safely so that no polluting substances are released?
- What role does Rijkswaterstaat play in processing and managing mineral flows and waste?

Questions about circular economy:

- According to Rijkswaterstaat, what is the government's role in the transition of companies, and specifically companies that work with mineral flows and mineral waste, to a circular economy?
- According to Rijkswaterstaat, what are the biggest obstacles to achieving circularity within the mineral flows and mineral waste sector?

Questions about rules/regulations from the government/Rijkswaterstaat:

- What are the most important rules and regulations that the mineral flows and mineral waste sector must adhere to?
- Have any new regulations or regulatory changes been introduced recently that have impacted the practices of the mineral streams and mineral waste sector, specifically targeting the transition to a circular economy? If so, which ones?
- Will new regulations or changes be introduced in the (near) future specifically targeting the transition to a circular economy? If so, which ones?
- Are the practices of the mineral flows and mineral waste sector in line with the regulations? If not, what violations are being committed and by what kind of companies?
- What is Rijkswaterstaat's opinion on the current state of affairs in the mineral flows and mineral waste sector considering a circular economy?

Appendix II
Code Tree