Assessment of an Alternative Funeral Method:

The Urban Death Project

Research Report for the course Interdisciplinary Project Groups (IPG)
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Abbreviations

IE	Industrial Ecology
IPG	Interdisciplinary Project Group
UDP	Urban Death Project
LCA	Life Cycle Assessment
ULO	Urban Land Occupation
SWOT	Strength, weakness, opportunity, and threat analysis

About this report

This report is divided into two main sections: the consultancy report that starts at page 7, and the scientific report starting at page 39. The consultancy report gathers the main findings of the conducted scientific study, communicates the results in an accessible manner, and discusses these findings with a broad multidisciplinary approach. The scientific report includes the detailed descriptions of the conducted scientific research including methods, models and calculations. Throughout the consultancy report, we will therefore refer back to the material presented primarily in the scientific report, where one can find more throughout scientific information.

CONSULTANCY REPORT

Chapter 1 Urban deathcare

1.1 Introduction

Death is an inevitable part of our lives. There are many different beliefs, often tied to religion, on what happens after passing away. But there is one view that is common for all modern humankind: the deceased should be honoured and disposed with respect. This so called *deathcare* has many forms and practices that have developed over the course of human history. Over time the different forms and practices of deathcare have developed into important cultural traditions.

There are three trends that are increasingly affecting the deathcare practices of today: population growth, urbanization and environmentalism. The number of deceased is growing steadily and these deceased are increasingly located in small urban areas characterized by a lack of space. These two trends together with the tendency of wanting to memorate the deceased close to one's home are leading to an overcrowding of cemeteries. Due to human imposed climate change, the environmentalist movement is growing and sustainability is becoming an inherent value of all human practices, thus deathcare as well.

Several novel technologies have been developed as environmental alternatives to the traditional methods of deathcare, burial and cremation. Of these alternatives, a start-up called the UDP claims to have realized a technology that is not only environmentally superior to the established methods, but also a solution to the issue of space in urban areas. This so called recomposition technology uses the natural process of composting to dissolve the body in a controlled setting. Over a time of six to eight weeks, the body decays into nutritious soil that is full of life-enhancing potential (Spade, 2015).

There are compelling arguments for UDP's proposal about its sustainability, however many questions with regards to environmental impacts, social acceptance and economic dimensions remain without robust answers. Therefore, in the light of the trends discussed before, it is of great importance to quantify the impacts of recomposition in comparison to other deathcare methods and to assess how well they can serve the ever-growing and aging population in an increasingly dynamic society. The purpose of this research is thus to study recomposition in comparison to four other funeral technologies: burial, cremation, resomation and green burial, in terms of life cycle assessment and land use, as well as study the socio-cultural and economic dimensions of all these practices. The main research question of the study is the following:

From the point of environmental impact and socio-economic context, can recomposition be a viable alternative to traditional burial, cremation, green burial and resomation in an urban setting?

The first chapter of the consultancy report will continue with elaboration of the history of funeral practices in the US, as well as a definition of the four funeral methods under study. In chapters two and three, the main research divides into two distinct chapters discussing the main findings of the environmental and socio-economic study. Finally, in chapter four, all the main findings are presented and the strengths and weaknesses of recomposition assessed.

This research report is directed towards the UDP with the intention to contribute to already existing research on recomposition and its implications for people and planet. However, it can also offer useful information to funeral homes, other funeral technology representatives or those recently lost a loved one in search of a suitable funeral method. Have a pleasant read!

1.2 A short history of deathcare

Throughout human history, honouring of the deceased has formed an important cornerstone of many cultures that are still relevant today. The way in which the body of the dead is handled is central to these practices. In this chapter, the short history of different deathcare practices is presented together with a comprehensive timeline. Afterwards, the present role of these practices in the United States is elaborated more in detail.

1.2.1 The emergence of burial and cremation practices

The first remarks of deathcare practice can be traced to the Neanderthals, at least 50 000 BCE (Than, 2013). The scientist agree that the hunter-gatherers started burying their dead not only to avoid the vicinity of predators but also for the remembrance (McCorkle, 2010). Their ritual included an attentional burial of the body, as well as placement of animal bones and flowers on the grave as a way of remembrance. Burial is therefore the oldest form of deathcare and remained as the dominating practice in most parts of the world for eras.

A practice that started because of its pragmatics slowly developed spiritual dimensions as the years went by and the human cultures became more diverse and sophisticated. In Mesopotamia, about 5 000 BCE, burial was practiced not only for the convenience of not attracting predators, but also for spiritual purposes. The people believed that the afterlife was underneath their feet, and could be accessed more easily if the dead were placed underground (Kramer, 1963). Similar funeral practices were taken upon Mayas in America (Stuart & Stuart, 1993). The common Egyptians would also get buried underground upon passing away, as well as pets, together with a set of tools to prepare for the work in after life (Ikram, 2015). Only the rich and important would be buried in a pyramid. In about 3 500 BCE mummification became prominent in the Egyptian culture, which was the predecessor of the modern embalming practice (Ikram, 2015). The use of casket-like structures emerged also in ancient Egypt and Mesopotamia. The dead would be placed in a funeral container made from cloth, wood or paper. In Europe, the Celts were among the first to start making caskets out of stones around 700 CE.

The first evidence of cremation can be traced back to 38 000 - 67 000 BCE (during Pleistocene, or more commonly Ice Age) in Australia, where the oldest cremation remains have been found at Lake Mungo (Bowler, Jones, Allen, & Thorne, 1970). In around 7 000 BCE., urns gained popularity as housing the cremated remains of the deceased. Cremation was popular in the Ancient Roman times, up until 2nd CE. In the Roman culture, the cremation rite included taking the body to the necropolis - the city of death - and burning it on a pyre, after which the remains of bones and teeth would be collected and placed in an urn (Fife, 2012).

Since their first appearance both burial and cremation had eras of preference in different parts of the world, highly dependent on their respective cultural context. When entering the Christian era, burial became soon the only accepted form of burial (Lemos, 2003). With the discovery of America and its colonization, the Europeans brought the tradition of burial with them, and consequently burial remained as the only accepted form of deathcare in United States until the late 19th century.

1.2.2 From tombs to modern cemeteries

Where the bodies would be places upon dead changed significantly over time. The graves originating from the prehistoric times are called grave fields, and often involved a placement of mud and stones over the corpse. These grave fields would often be located to a beautiful nature site. The predecessors of modern cemeteries, tombs and necropolis, can be found in several ancient cultures. In 100 CE, the Romans started building the first columbariums, places to store the urns holding the cremated remains (Toynbee, 1996). From 700 CE onwards in Europe, the graves were strictly operated by the church. These were mass graves based on composting of the bodies, located in the urban setting of churchyards. Only important and powerful people/families would be allowed their own crypt, often in the catacombs of the church. During the 19th century, with Napoleon's conquests across Europe, the graveyards began to change in terms of location as well as their ownership. Due to infectious diseases, the cemeteries would be built far away from the cities, under the control of the government instead of the church (McCorkle, 2010).

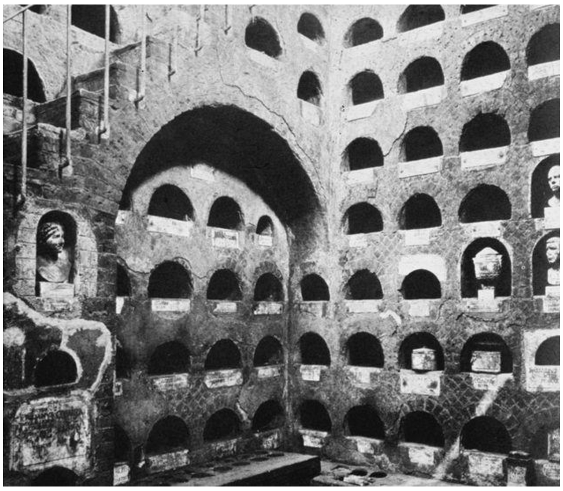


Figure 1: Antique columbarium

1.2.3 Developments in the modern United States

Up until 19th century America, the dead were buried next to one's home or nearby. The modern large-scale cemeteries appeared in the United States in 1836 (Prothero, 2001). In the late 19th century the modern embalming practice emerged for the first time in connection with traditional burial. The American Civil War and the need to return bodies to the families was the reason for the new adaptation of the ancient Egyptian practice. Embalming became soon the standard due to sanitation and social dimensions of funeral practices. It was also a practice requiring specific knowledge and was thus performed by educated caretakers at a specified location (Laderman, 2003). The first school of mortuary science was established in the United States in 1882, which contributed to the growing importance of the funeral industry (Laderman, 2003).

Burial remained as the norm of deathcare until the late 20th century. In the 1980s, cremation started gaining popularity, and today cremation appears to have slightly overtaken traditional burial (Josh Sanburn, 2016). In the modern United States, the first record of cremation was in 1876 in Washington, Pennsylvania, an event that divided the people between celebrators of new scientific era and those considering cremation as a deed of a devil (Prothero, 2001). The years leading up to and following this cremation were fuelled with the same debate, where advocates of cremation claiming it to be technologically superior, sanitary as well as more spiritual (Prothero, 2001).

Today, cremation and burial are neck and neck with popularity in the United States. In Washington State, cremation has even overtaken burial, claiming 70% market share. According to the Cremation and Burial report of 2015, roughly one third of funeral homes in the United States operate their own crematory. As the popularity of cremation is predicted to grow even further, another 10% of the funeral homes are planning on opening their own crematorium within next five years. Factors contributing to the prevailing of the ancient practice include the economics of funerals, sustainability concerns, the diminishing importance of religion leading to less prohibitions as well as a trend of simpler and less ritual funeral practice (NFDA, 2016). The growth of cremation has also been contributed by urbanization and limited land capacity.

1.3 Funeral technologies under study

The common technologies

TRADITIONAL BURIAL 1

In modern day burial, the body is layed down into the ground 6 feet deep horizontally in a casket at a controlled cemetery. Burial often involves a use of burial vault, a concrete box that encloses the coffin and prevents the grave from sinking. If the body is to be displayed for a wake before the burial, enbalming is mandatory. A headstone is placed on top of the burial site to mark the grave and create a place of remembrance for the deceased.


Grave yard

source: Wikipedia (n.d.)

source: The Times News (2017)


Cremation facility

CREMATION 2

The technology involves burning of the body in a special cremation unit and placing of the ashes in an urn. The body has to be enbalmed before the process, if displayed at the wake. The urn can be either buried at the cemetery, placed in a columbarium at the cemetery or taken home. Often the ashes are scattered to the nature.

GREEN BURIAL 3

In green burial the body is layed horizontally into a grave at special green burial site, often located at the rural areas. The practice allows only natural components that will decompose effortlessly into the ground (eg. Biodegradable casket). In case of a viewing, the enbalming is done formaldehyde-free. No artificial headstone is placed on the grave, but instead natural rocks or a GPS system may help identifying the individual graves at the green burial site.


Green burial site

source: Seven Ponds (n.d.)

The new technologies

RESOMATION 4

Resomation is a funeral technology which is claimed to be environmentally superior to traditional methods. It involves placing the body in a specially designed wool coffin in a water based solution of alkaline hydrosis, in a special resomation unit (pictured). The resomation process takes 3-4 hours, and after the resomation process, the flesh and intestines have completely resolved and only the bones remain. The bones are grinded to a powder, which are placed in an urn in the same manner as in cremation. (www.resomation.com)

Resomation facility

source: My Send Off (n.d.)(

RECOMPOSITION 5

The Recomposition technology developed by the Urban Death Project (www.urbandeathproject.org) is based on natural composting. The body is wrapped in a cotton cloth and layed in a special composting unit (pictured). Alfalfa and woodchips are added to the "tower" to foster the composting process. During the course of 6-8 weeks the body decomposes into nutrious soil which is used in the surrounding memorial garden. The relatives are also encouraged to take soil with them to nourish their own garden.

The Urban Death project aspires Recomposition to be a sustainable, meaningful and equitable alternative to traditional forms of death care, especially in dense urban areas.

Recomposition tower

source: The Seattle Times (2016(

Plan for UDP's Recomposition site

source: Kickstarted (n.d.) (c) Katrina Spade

Chapter 2 The social context

2.1 Socio-cultural perspective

From the moment of birth until the moment of death, each human attains a unique configuration of personal and social norms. The behaviour towards death is largely derived from traditions rooted in local religion and culture. However, upon entering the Information Age, these spatial distinctions have been becoming increasingly blurred. At the same time, behavioural patterns are being replaced by unconventional motivations of the individual.

In terms of being a taboo topic, death has almost come full circle over the course of history in Western societies. And while there is an increasing interest in conducting research around all things death-related, communicating openly about the way people perceive, manage and experience the death of themselves or somebody close, is still rarely achieved.

Cremation was accepted by the Church in 1963 and rapidly adopted since. The emergence of the environmental movement in the late 20th century has led to a variety of technologies and methods in the deathcare industry. Both factors illustrate an acceleration in the evolution of this industry on a technical level. Changes of methods inevitably lead to the involvement of legislator and other stakeholders.

However, little is known about the motivations and decision-making processes of modern adults when faced with a choice of funeral methods. How much knowledge do they have? Which factors take priority? And in the context of this study, what is the likelihood of people accepting recomposition as an alternative deathcare method?

The lack of perfect information is the challenge every decision needs to mitigate. In order to know how the prospective clients of recomposition providers such as the UDP will approach this method and either choose or

reject it, it is essential to seek information from this group directly. However, due to the spatial and temporal limitations of this research, a mediated method was chosen to gather data from the UDP's target area of Greater Seattle. For the purpose of feasible communication, the population's opinions and positions would be relayed by representatives of the 7 major faith groups, which was chosen as a reasonable basis for segmentation. To that end, an online survey was created and sent to one representative from each council district in Seattle. Further, one funeral home from each district was also contacted with an adjusted version of the same survey.

In addition, a literature review was carried out, which was largely based on the journal Mortality. Further, the research team conducted a number of informal interviews with stakeholders of the deathcare industry in the Netherlands. As a result, some of the findings from the survey were corroborated by the additional information or vice versa.

While participation rate of the survey was low, the responses illustrate a fundamental change in the way people approach funerals. The importance of tradition and religious authority is fading and being replaced by an increasing variety of considerations such as environmental impact, cost and honoring the life of the deceased. In effect, people are more likely to look at alternative deathcare methods to best fulfil a range of requirements.

The complementing nature of survey, literature review and interviews cannot hide the fact that there is still little detailed understanding of people's behaviour in the emotionally charged circumstances of death. Yarden, a funeral non-profit in the Netherlands, responded to this information gap with direct, sober and frequent communication with its audience in an attempt to neutralize any hesitation people might have in talking about deathcare.

Research efforts around the world indicate a growing body of knowledge around funerals and deathcare, from environmental studies in the Netherlands and Australia to social and economic projects in the US and the UK.

The UDP can utilize this wealth of information to convincingly communicate its mission to an already receptive audience in the Seattle Metropolitan region. To a lesser extent, the situation is the same across the US, where the non-religious population represents a smaller share. Especially among Catholic followers, limitations in the Canon Law and their personal interpretation by authorities is a significant barrier. The burial of the whole body is not an argument anymore, since cremation is an acceptable method.

This study shows that the level of social perception of recomposition justifies the development and implementation effort by the UDP. The most significant points of leverage will be the bridging of the information gap between the deathcare industry and its stakeholders, as well as refining its method in order to comply with religious laws such as the essential provision of blessed grounds for Catholic funerals.

2.2 Economic perspective

When talking about the economics of deathcare there are a few important aspects. The first of these aspects is a clear overview of the importance of the financial burden of the manner of deathcare to people. In other words; *to what extent do the financial implications of deathcare influence the choice in manner of deathcare*? Another important aspect is the actual costs of the different funeral technologies. Since several authors in the field (Bern-Klug, Ekerdt, & Schild Wilkinson, 1999; Corden, Anne, Hirst, & Michael, 2013) stress the need for more clarity, it is important to look into the costs of the different funeral technologies and make this known to the consumer. Therefore, the following question is posed; *what are the costs of different funeral technologies*? In light of the need to take responsibility over the impact that humans have on the environment and the proposition of UDP to implement fair-pricing the following question is composed; *can the redistribution of shadow costs over different income levels provide a way to implement a fair-pricing model*? These three subquestion help to answer the main research question *"does the economic context serve as a driver or barrier for the development of recomposition"*?

To answer all these questions the economic research is divided into three parts. First, surveys were held amongst religious representatives and funeral directors in Seattle to get a perspective on the influence of the economic costs of the different funeral technologies. Second, an overview of the costs of the different funeral technologies is composed by using information from funeral homes in the Seattle area, available survey results, literature research and own calculations. Finally, using the shadow costs composed by Keijzer (2016) and the outcomes of the LCA study, the environmental impact of the different funeral technologies is added to their prices and redivided over the different income levels which makes fair environmental compensation possible. All information used for this research is taken from research applicable to the Seattle area or Washington State.

Since the amount of respondents to our composed survey was not high no definite conclusions can be drawn. The six religious representatives that responded to our survey stated that financial implications do not play a very significant role in choosing a funeral technology. However, the funeral director that responded did think financial implications play a significant role in the choice of a funeral technology. These answers contradict each other but are not completely unexplainable. As the funeral director is more likely to talk about the financial implications of a funeral technology since this is part of his or her job it is not surprising that he or she answered that financial implications are very important in the choice for a funeral technology. Since the religious representatives probably talk more often about the spiritual meaning of the different funeral technologies, money is a less likely subject of conversation. However, these are generalizations and more research into this is needed. Furthermore, the seven respondents are hardly representative for the entire Seattle area which means conclusions cannot be drawn from these answers. Therefore, further research into this topic is advised by means of a more complete survey with more questions focused on the economic aspect of deathcare and more respondents. In conclusion, the question to what extent the financial implications of deathcare influence the choice in manner of deathcare cannot be answered by this research.

In order to compose an overview of the costs of different funeral technologies in Seattle information on pricing was taken from several funeral homes in the city (Columbia Funeral Home, 2014; Howden-Kennedy Funeral Home, 2014; White Eagle Memorial Preserve, n.d.). All prices exclude extras such as a memorial service, flowers and headstones and focus on the processing costs, the costs for a casket or urn and the costs for placement of remains. As recomposition is not a currently practiced funeral technology, the prices for this were composed based on information that was available of other technology and provided by dr. Hottle.

The outcomes of the calculations show that burial is by far the most expensive funeral technology (see Table 1). Cremation and resomation prices are almost equal, resomation being the slightly cheaper alternative. The cheapest funeral technology appears to be recomposition. Since the difference between resomation and recomposition is almost a thousand UStra dollars it seems that even if an error margin is included in the calculations of the costs for recomposition this technology will stay the cheapest one. However, it is important to note that cremation and resomation prices include the placement of remains in our calculations while according to dr. Hottle (2017) it is not a common practice to bury the ashes in Seattle. When excluding the costs for placement of remains of cremation and resomation, both show to be cheaper than recomposition. More research is needed on the prices for the recomposition process and the placement of the remains of this funeral technology in order to compose a more complete overview of the costs of this funeral technology.

Shadow costs provide a means to include environmental impacts of the funeral technologies in the costing policies of those technologies. The shadow costs for green burial and traditional burial are the highest due to their land-use. For resomation the shadow costs are the lowest followed by cremation. Although UDP advocates recomposition as a rather environmentally friendly funeral technology, it actually has a quite high shadow cost since it scores poorly on the climate change impact category.

Since UDP suggested that the price for recomposition should depend on the income level in order to lessen the financial burden on lower incomes, a fair-pricing model is required. How should these different prices be composed among welfare categories? This research suggests to use the shadow costs as a means of distributing the prices fairly over the different income levels. The five different income classes in this model are paying the consumer costs plus the shadow costs. The shadow costs, however, depend on the level of their income. Since over fifty percent of the Seattle population is part of the highest two classes, these classes pay partly for the other classes, as well as for themselves. More research is needed on the percentage of people of each class that are likely to opt for recomposition to even out imbalances.

Table 1: Final pricing of alternatives

Funeral technology	Burial	Cremation	Resomation	Green burial	Recomposition
Consumer costs	$10,054.00	$3,340.00	$3,485.00	$5,345.00	$2,466.00
Shadow costs	$229.90	$24.04	$20.51	$363.54	$37.40
New consumer costs	**$10,283.90**	**$3,364.04**	**$3,505.51**	**$5,708.54**	**$2,503.40**

To conclude, the environmental impact for the different funeral technologies can be accounted for by implementing shadow costs into the prices for the different technologies. Furthermore, the redistribution of the costs over the different income levels can be done by redistributing the shadow costs. However, to what extent this provide a good fair-pricing model is debatable since the shadow costs only make up a very small part of the final consumer price. Suggestion is therefore to do more research on the redistribution of the price for recomposition to lessen the financial burden on the lower incomes more than the suggested model has done.

If all three aspects that are discussed above are regarded, no conclusive answer can be given to the question if economic context serves as a driver or barrier for recomposition. From this research, it's not clear to what extent financial implications influence people's choice for a funeral technology. This would therefore not be a driver, nor a barrier. As the consumer costs for recomposition are in the same range as the costs for cremation and resomation this appears to be driver. However, the calculation of the costs for recomposition are based on a lot of assumptions. Finally, including the shadow costs in the prices for the funeral technologies and compose a fair-pricing model out of a redivision of the shadow costs would neither be a driver nor a barrier. Since the suggested fair-pricing model doesn't lessen the burden on the lower income profoundly, a better model should be composed. In case a better model is composed, this aspect could be a real driver for the UDP since it would allow them to potentially attract more customers. Finally, the only conclusion that can be made is that the economic context most certainly does not serve as a barrier for recomposition. The question whether it would be a driver should be addressed by further research.

Chapter 3 Environmental impacts of deathcare

3.1 Land occupation

When discussing deathcare and the environmental implications of these practices, land use is probably the most notable one as land use occupation can be observe every day in the form of cemeteries. Traditionally, cemeteries have been located in city centers, allowing an easy access for the relatives to come and visit. In this manner, cemeteries are serving not only as a place of remembrance and respect for the deceased, but also as places of nature and recreation. Cemeteries can increase the biodiversity of cities and accommodate wildlife rarely found in dense urban settlements (Barrett & Barrett, 2001).

In a densely populated area where urbanization continuously increases such as Seattle, land is scarce and valuable. Use of land for deathcare becomes an important issue. Due to population growth, both the city as well as the cemeteries face challenges in regard to overcrowding. Currently existing cemeteries remain as important places of remembrance, peacefulness and biodiversity in a rumbling city, but there is no space in the city planning for new cemeteries to accommodate the deceased.

Partly due to this overcrowding, cemeteries are nowadays more commonly built around the outskirts, where land is less valuable. This development is not optimal for the relatives of the deceased, who presumably still live in the cities and need to travel further to visit the place of remembrance. The recomposition technology as proposed by the UDP claims to solve the spatial problems of deathcare in urban areas. Traditional deathcare methods involve all use of land for the individual bodies, through means of an eternal grave or a cremation with a buried urn. As recomposition does not have such an individualistic approach to deathcare, it is believed that recomposition has a tremendously lower environmental impact in terms of land use. There currently is no primary scientific proof of this yet. That is why a dynamic land use study was conducted as part of the research on the environmental impacts of recomposition.

The land use study, laid down more explicitly in chapter 9, is composed of a literature research and a model of the system of land use of funeral technologies in Seattle. Individual technologies are compared and a number of scenarios is created to contribute to analyse a mixture of different technologies. The model runs for 83 years - from 2017 until 2100, and includes the population dynamics in terms of natural population growth and net migration. The results indicate that recomposition would require roughly 87% less land than traditional burial. Recomposition performs slightly worse than cremation and far worse than resomation.

An important notion of the burial practice in the United States is that graves are for eternity. Unlike the Dutch situation where graves are recycled due to overcrowding, a similar practice is not prominent in Seattle. Not implementing this practice results in a negative impact on the land requirements of deathcare, as it enforces the spread of cemeteries and prevents the demolishment of age-old cemeteries with little to no remembrance value for anyone. Cemeteries already account for an estimated 1,93 km^2 of the land in Seattle and if only burial would be advocated from now till the end of the century, this space requirement would more than double.

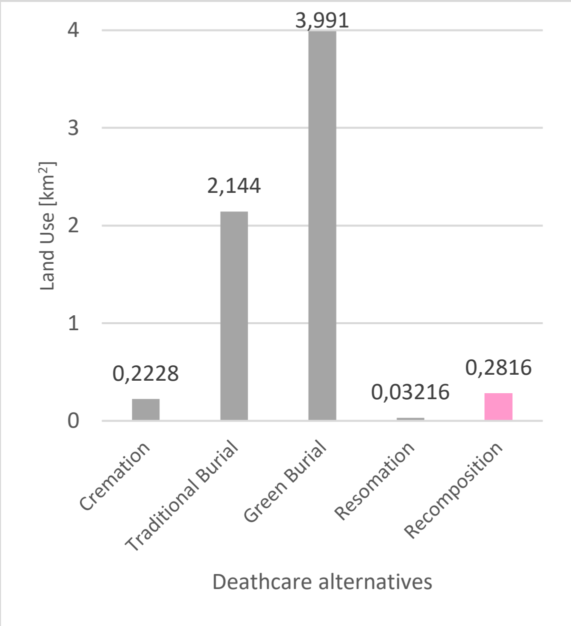


Figure 2: Additional land-use of 100% alternative application until year 2100

Cremation, like resomation, does not require much land. Both of these technologies have similar space requirements when it comes to performing the procedure, as well as a similar end product that is stored in the same manner. The difference between the land use requirement between these technologies comes from the assumption of what happens to the resomated remains - for cremation, 36% of the cremated bodies get buried at the cemetery and 7% placed in a columbarium (NFDA, 2015). Unfortunately, similar data does not exist for resomation, and thus it was assumed that 5% of the resomated remains are buried and only 2% placed in columbarium. Overall, the land use results for both cremation and resomation are volatile to change in response to personal preferences, which are expected to be mostly determined by economics. The more expensive placing the remains in a grave or a columbarium becomes, the less people are willing to opt for these options as taking the remains home is free.

Green burial requires the most land by far. However, it takes place in rural areas outside of the city center of Seattle and thus does not contribute to the overcrowding of cemeteries. If all deceased in Seattle up to 2100 would be processed through green burial, roughly 4 km^2 land would be required. It is important to keep in mind that this land is (or would become) natural green space. However, advocating green burial on a large scale in urban metropolitan areas has its own limitations and challenges. Commuting to the place of remembrance is one such a challenge that will be discussed in more detail later on in chapter four.

Recomposition has a unique characteristic in comparison to the other technologies: the facility constantly renews its capacity to process the deceased. It has been estimated by Dr. Troy Hottle that a recomposition facility of 1.600 m^2 can process one body per week, resulting in 52 bodies per year. This means that in order to offer deathcare for all the 9.126 people dying in 2100, 176 recomposition facilities should be in operation. This may sound a lot but as the results show, land required to realize this would only be 13% from that of burial. As we know, the technology is still in development and it is likely that system improvements will follow, resulting in a higher capacity later on.

Three complementary scenarios were created in order to demonstrate how certain mixes of the traditional and novel technologies would perform in comparison to the advocation of solely cremation and burial. Scenario 1, The Lock in, presents the land use requirement by deathcare in 2100, if the current situation would lock in: 75,5 % advocating cremation and 24,5 % traditional burial. This would result in a total land use of 2,62 km2 , which in Figure 3 is presented as 100%. Scenario 2: The New Green Movement, would involve 25% advocation of each cremation, resomation, green burial and recomposition technologies and result in 80% less land use than in the Lock In scenario. Scenario 3: The Paradigm Shift, was constructed to model a scenario in which recomposition would become the new norm, advocated by 70% and accompanied by 30% resomation. In the end, it performed slightly worse than the Scenario 2. This is most likely due to the fact that this scenario involves 25%

of green burial, of which the land use is not taken into account in the urban land use. Thus, it is expected that the most sustainable scenario in terms of land use would be a mixture of Scenario 2 and 3: one in which resomation, recomposition and green burial are advocated simultaneously.

3.2 Soil, water and air pollution

One of the reasons why the UDP was founded is to provide an alternative to the relatively polluting funeral methods that are currently available in urban settings. These pollutants, which spread through soil, water and air, affect impact categories (which will be explained in the next chapter) and therefore the quality of the environment around us.

By using the elementary composition of the human body as input for a landfill model (as was used in studies by Keijzer (2011, 2016; Keijzer & Kok, 2014) the emissions of the human remains to the environment were calculated. As was learned during the LCA study described in the next section, each alternative has a distinct set of emissions that are released to the environment through soil, water and air. In order to analyse the impacts of the funeral technologies in the next chapter, this chapter aims to answer the following research question:

What are the main emissions (to soil, groundwater, air) that can be expected during the composting of human remains?

The human body contains a wide variety of different elements that all enter the soil when the remains are processed through recomposition. Although there are some artificial elements to this process, the core is based around the natural decay processes. Through these processes, the elements in the soil adapt to emissions that are able to spread to water and air. Others remain in their elemental form in the soil. The findings of the study on these emissions have been incorporated in the LCA analysis.

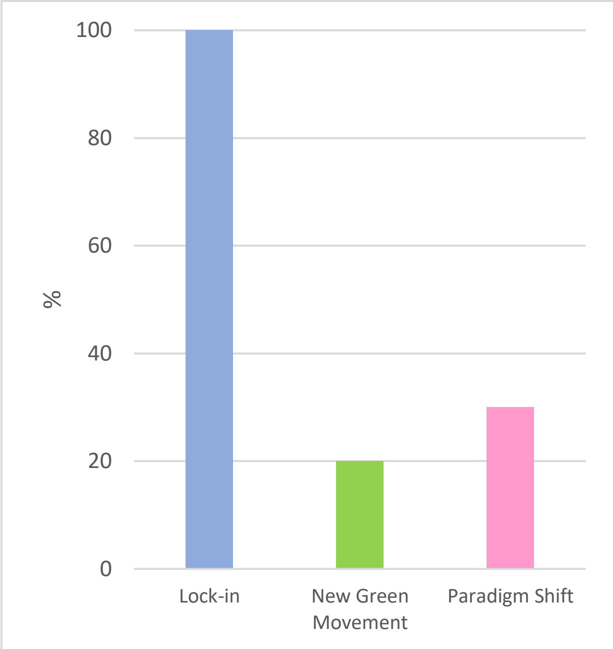


Figure 3: Land use relative to the worst performing

As important as the emissions from the human body are to take into account, the largest source of emissions originates from composting the added biomass. Due to the aerobic nature of the composting process inside the recomposition facility, the most notable gases escaping to the environment are NH_3, N_20, NO_2 and CH_4. Additionally, CO_2 is produced, but this is biogenic of nature.

As the body decomposes, there is a chance for previously encaptured pathogens to escape through the soil into the groundwater. Especially because the concentration of the processed bodies is higher than on i.e. cemeteries, the reduction of the spread of pathogens is important to consider as integrated part of the recomposition facility. Based on literature study, the following recommendations are made to the UDP. As it turns out, most of these measures also help to increase the speed of the decomposition processes. An overview is provided in Table 2. More information can be found in the scientific report (chapter 10).

Only the texture / pore size of the soil has contradictory benefits. The UDP will have to decide whether higher process speeds are required, or the spread of pathogens needs to be further minimised. This decision can realistically only be made once more data has been gathered through the current pilot project, or more specific, new pilot projects have started.

Table 2: Overview of theoretical optimization measures

Measures to theoretically* increase the speed of decomposition process	Measures to theoretically* decrease the spread of pathogens through soil
High process temperature	High soil temperature
High moisture content of the soil	Soil PH above 7
Coarse-texture of the soil	Soil with high adsorption capacity / small pore size
Supply of oxygen	Amount of (rain) water that pours onto the soil
	Nearby rooted plants and trees

** The UDP is the first organisation to build a facility with the purpose of industrially decomposing human remains. Although a pilot project is running, no actual data has been proven true yet in this specific situation.*

Another potential risk is the remains of medicines present in the body, but most studies seem to agree that these have been broken down by the body (as they are designed to) well before the body is processed.

Reflecting upon the research question "*What are the main emissions (to soil, groundwater, air) that can be expected during the composting of human remains?*", it can be concluded that the main emissions as a result of composting human remains in absolute values are 1.3 kg CO_2 and 0.96 kg methane to air, 0.14 kg SO_4, 0.52 kg PO_4 and 0.18 kg N to water.

3.3 Comparing alternatives

For a complete assessment of the main environmental impacts associated with funeral technologies, identification of points for improvement and a comparison of different technologies, a life cycle assessment (LCA) study has been done (see the scientific report, chapter 11). It is important to take a life cycle perspective in order to discern where in the system the main environmental impacts occur. A software model has been built in openLCA and delivered to the commissioner. This model can be used in the future to perform LCA studies as process-specific knowledge increases. The complete study can be found in the scientific report.

The result of the LCA is a quantified list of environmental impacts in different categories.

It is found that the main environmental issues of the funeral industry in the US market are related to urban land occupation, marine ecotoxicity, human toxicity, freshwater eutrophication, freshwater ecotoxicity and agricultural land occupation. The most serious impacts are urban land occupation from traditional burial and freshwater eutrophication for cremation, from the scattering of ashes. Given the fact that these technologies are and probably will remain the dominant ones, it is important to improve these technologies in those areas. Considering a full range of environmental impacts, each of the technologies has their own area of concern. Overall, recomposition seems to perform average, environmentally outperforming other technologies in some areas and scoring worse in others. Table 3 illustrates how often each of the technologies was either the best or worst alternative for an impact category. Burial clearly has the worst environmental performance of all. Green burial most often has the lowest impact. Remarkable is that resomation nowhere has the lowest impact. Recomposition and cremation seem to be in between.

A positive message for the UDP is recomposition outperforms the other technologies in each of the aforementioned impact categories related to the main environmental issues of the US funeral industry. This means that when looking at the funeral industry as a whole, the main environmental impacts are caused by the other funeral technologies. In order to make the (inter)national funeral sector more sustainable, it seems best to either increase the market share of technologies with lower environmental impact in those areas (recomposition, green burial and resomation in particular) or improve the environmental performance of the other technologies (especially burial and cremation).

Using shadow prices as a method to assess the costs associated with preventing or mitigating the effects of environmental impacts, recomposition seems to perform less well (see Figure 4 & Figure 5). In most cases, recomposition ranks in the middle of the alternatives. Especially its relatively high contribution to particulate matter formation, marine eutrophication and climate change causes it to be outranked by resomation and often cremation and as well. Besides these, it was found that fossil depletion and terrestrial acidification are also categories of concern. It must be noted that the values for land use in this LCA are issue of debate and therefore should be regarded with some reservation. Water depletion has been omitted because of flaws in the database.

The main contributing stages in the recomposition process are the composting process and the production of additional biomass. These affect all impact categories. The contributions for the main categories of concern for this technology are presented in Figure 6.

During composting, emissions of methane, dinitrogen monoxide, ammonia and nitrogen oxides cause the main impacts. Reducing the emissions of any of those would improve the performance of the system. Reducing ammonia emissions would especially influence particulate matter formation and terrestrial acidification. Reducing methane and dinitrogen oxide would reduce impact on climate change.

The production of alfalfa mix (this model uses extensively farmed hay as a proxy) is the main cause of the high impact of the biomass production stage. The recomposition process needs around 1000 kg of additional biomass per body. The sheer volume of biomass produced causes this stage to have an environmental impact that is hard to mitigate. Besides, the proxy used for alfalfa mix in the LCA model seems to be on the optimistic side of the spectrum in in terms of resource and energy use. It is likely that real-world production has higher associated impacts.

Funeral technology	Number of categories with best performance	Number of categories with worst performance
Traditional Burial	2	9
Cremation	6	4
Resomation	6	0
Green burial	10	1
Recomposition	7	3

Table 3: Summarized performance scores of alternatives

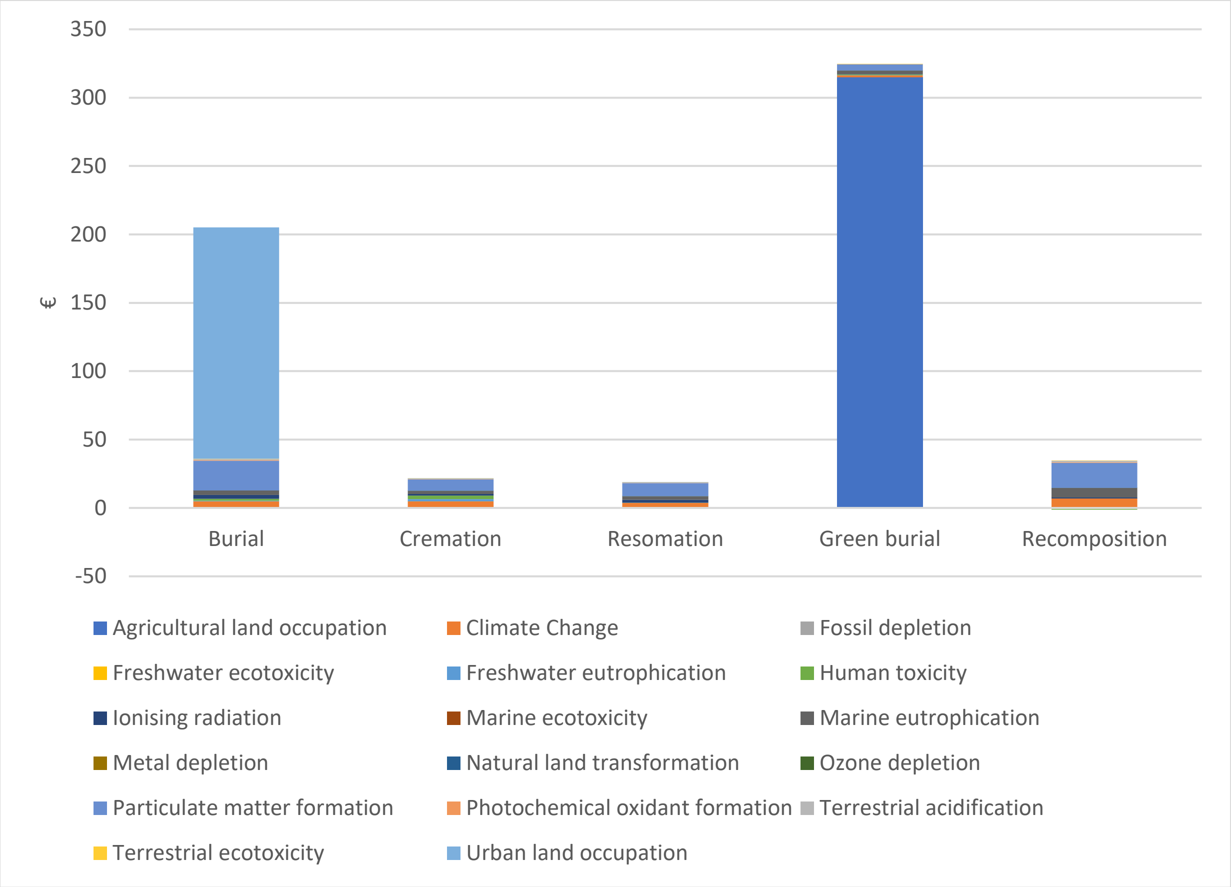


Figure 4: Shadow costs of the burial alternatives, excluding water depletion

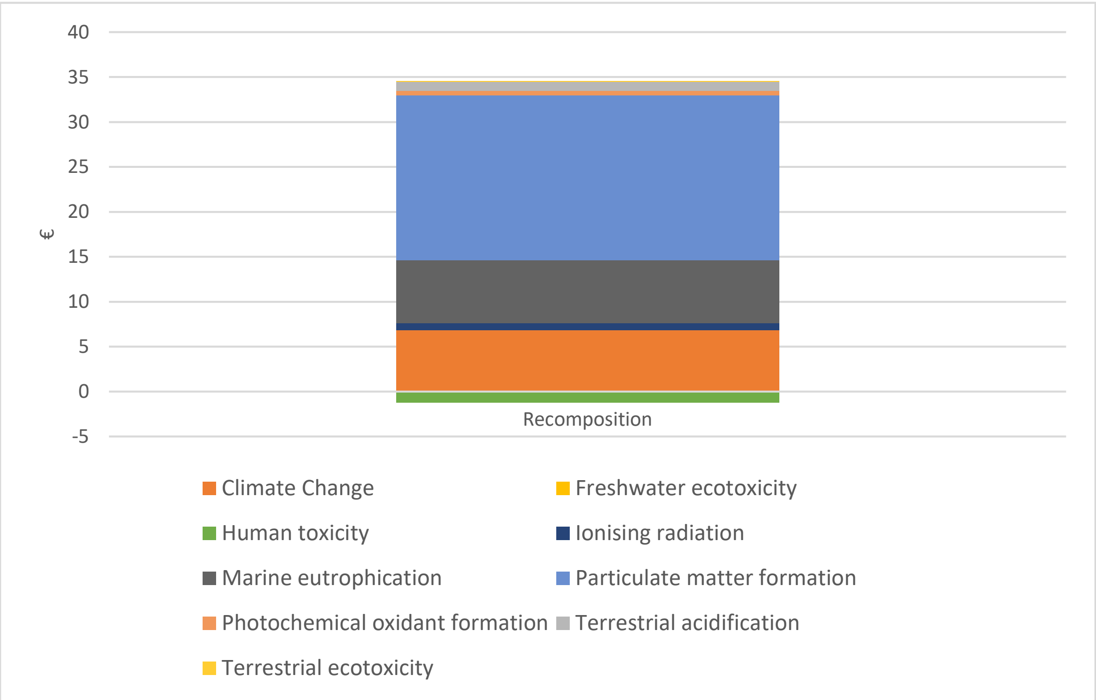


Figure 5: Shadow costs of recomposition, excluding water depletion

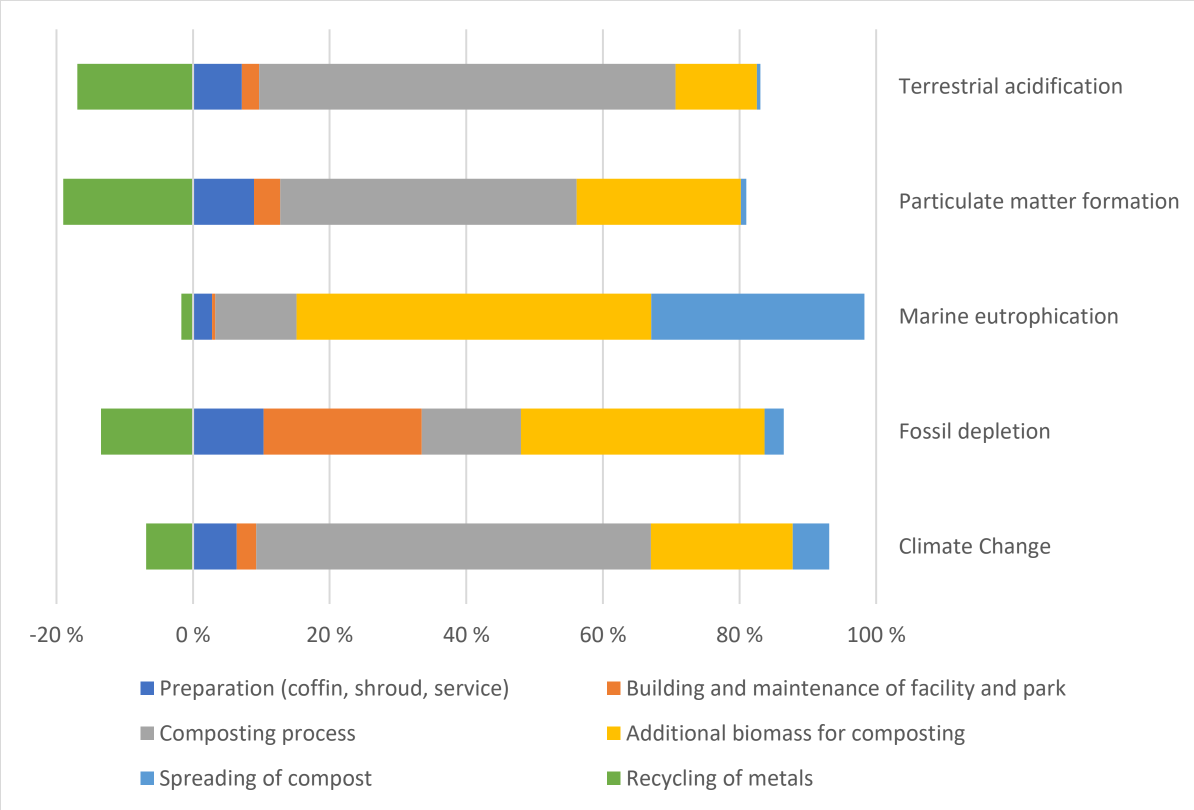


Figure 6: Contribution analysis main impact categories of main concern for recomposition

To reduce the impact on fossil depletion, electric or hand-powered memorial park maintenance equipment should be considered. To reduce the impact on marine eutrophication, it might be a good idea to look into ways of applying the compost that uses the available nitrogen as efficiently as possible, minimizing losses to ground water. Finally, it is worthwhile to look into more sustainable alternatives to the conventional cotton shroud.

Land use is a very important parameter in this LCA. Since, in the US, a burial provides an 'eternal' resting place, the environmental impacts associated with land occupation and graveyard maintenance are in theory infinite. This causes both traditional and green burial to perform poorly. However, the business model of the natural burial sites in the Netherlands causes the site to be transferred to nature conservation agencies once the burial ground's capacity is reached. This is expected to be after 20 to 30 years, depending on the size of the plot. If this business model is applied in the US, green burial is suddenly a very sustainable option (Figure 7). Transport is an issue for green burial, especially cumulative burdens from visitors to the funeral, but this can also be the case for other funeral technologies, depending on where relatives live.

This brings up another point for discussion. Keijzer (2011) found that surrounding activities such as correspondence, flower cultivation, food and beverage production and visitor transport make up 75-95% of the total environmental impacts of a funeral. Taking into account the relatively high impacts from transport of visitors, green burial might not be such a viable alternative for an urban setting.

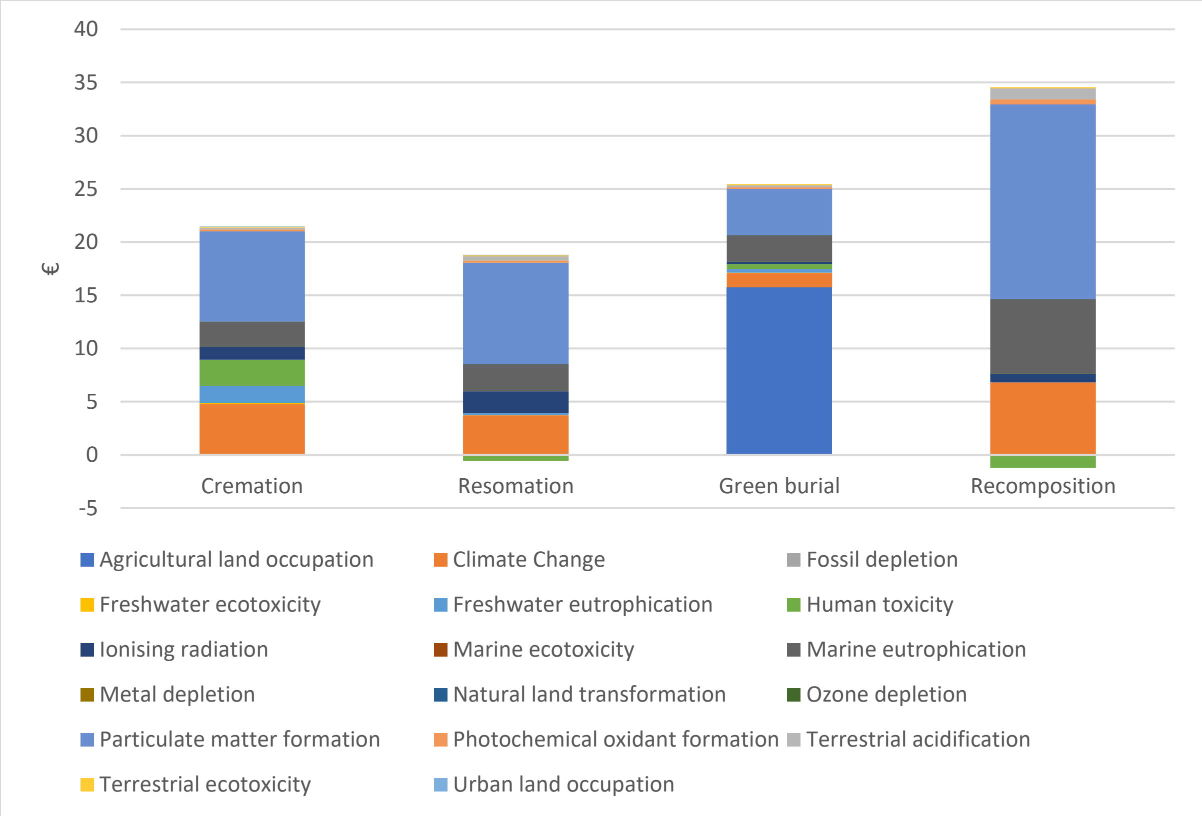


Figure 7: Comparison of shadow costs for alternatives with 25 years' time horizon for green burial in NL

A similar discussion can be held regarding recomposition. Given the high need for biomass that is grown in an agricultural setting, it can be debated whether recomposition is the perfect 'urban' solution to environmental problems of deathcare. Cultivating 1000 kg of biomass outside of the city and transporting it into the city for every recomposition seems not very scalable. Even more, 500 kg of compost is produced in the process. If people do not take that home (because they only want a little or because they do not have a garden) or cannot be applied in urban areas (e.g. for legal or public perception reasons), it has to be transported out of the city again. This is a serious point of concern for recomposition and should be considered in the further development of the technology and its business model.

A possible solution to this problem lies in the multifunctionality of the system. Recomposition can be seen to deliver at least two functions (three if you count the provision of green space in an urban area): The safe disposal of a human body and the production of compost. If the compost can be applied without legal or cultural restrictions, a part of the environmental impacts can be allocated to its production (consequent changes in LCA results are shown in Figure 8). Assuming the compost is used by somebody who would otherwise buy different compost, the process of recomposition avoids the production of compost somewhere else. Subtracting the environmental impacts of this so-called 'avoided burden' dramatically decreases the impacts of recomposition (Figure 8). Please note that this is just one way of dealing with environmental impacts in a multifunctional system. The important message to take home from this is that the multi-functionality of the system should be acknowledged and can be regarded as a strength.

In finding symbioses with urban biomass waste, such as garden or park clippings, the need for cultivation and transport from outside the city would be reduced. Furthermore, this would add yet a fourth function to the system: The waste treatment (or upcycling in this case) of urban biomass waste. This type of symbiosis asks for active collaboration with different stakeholders. Besides the environmental benefits, this has the added value of weaving the UDP more tightly into the local community. Discussing the different functions of the system and discovering possible collaborations is the starting point for making recomposition more sustainable.

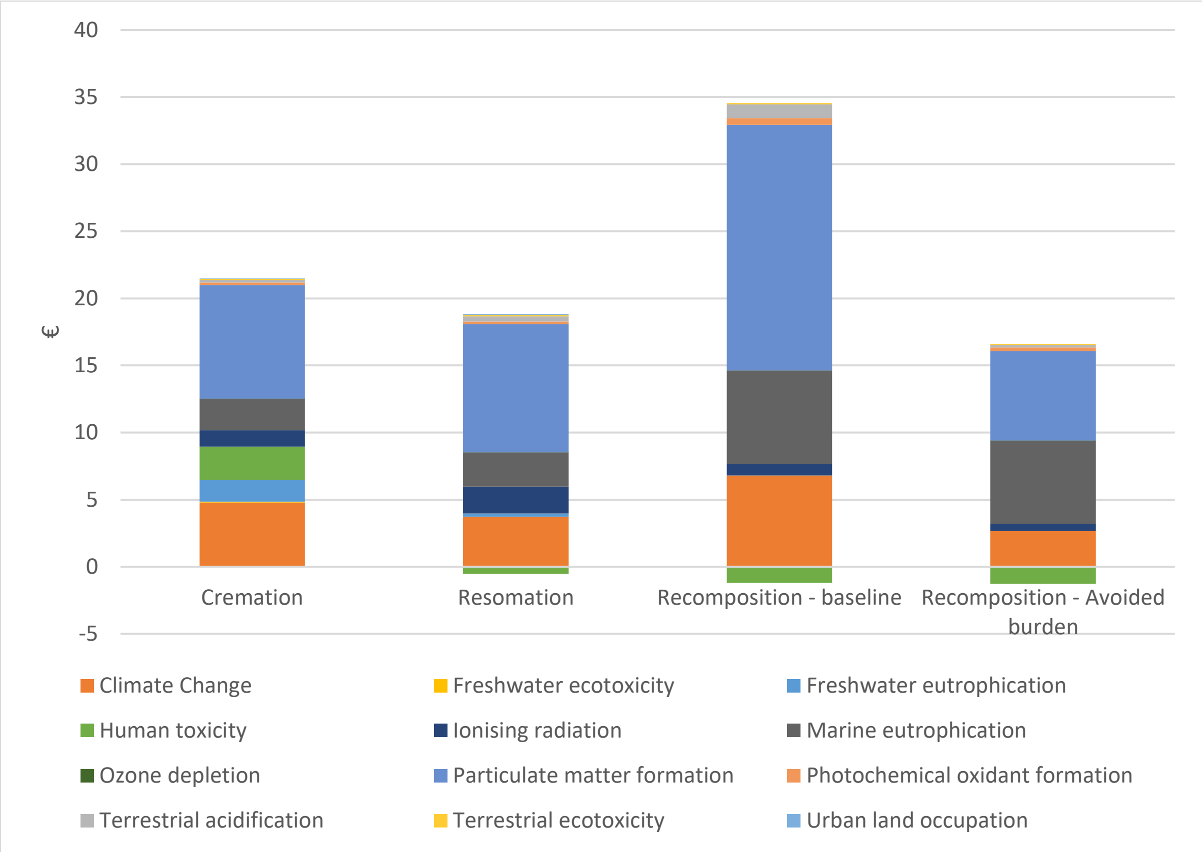


Figure 8: Comparison of shadow costs for alternatives including avoided burden scenario

Chapter 4 Dying sustainably

4.1 Deathcare for all

If there is only one thing that is certain in life, it is death. Over millennia, humans have developed a very special relationship with the dead and how to take care of them. This relationship is still largely based on individual or collective spiritual norms but has been increasingly affected by secular factors such as financial considerations and environmental concerns.

The Seattle Metropolitan region is among the most secular areas in the United States. In effect, communication about death and the deceased is not (as much) a taboo among Seattleites, who are environmentally aware and open-minded about technological innovation. The rapid adoption of cremation as a funeral method since its official acceptance by the Catholic Church in 1963 illustrates these traits. Deathcare has become a service industry, offering a range of methods and assistance with auxiliary tasks and activities. Clients of funeral homes require increasingly customized celebrations and rituals, which need to satisfy socio-cultural, economic, legal and environmental stipulations. Further, mourners nowadays have their own ideas about anything and everything from basic arrangements to elaborate extensions of the ceremony. The apparent complexity of deathcare in the 21st century is therefore one that cannot be summed-up in brief, but requires understanding of and catering for the individual.

There is a growing sense of procedural uncertainty about the future of deathcare. However, the recent and envisioned developments in the funeral industry also present opportunities for service providers and organisers, new technologies and methods as well as the extended community around the bereaved. In an economic context, this transition to a more liberal and diverse attitude towards deathcare leads to greater competition and growth in commodity and service offerings. Over 50% of funerals in the US are carried out as cremations, which is generally more affordable than traditional burial. The trend indicates a 75% cremation by 2035, but this does not adequately reflect the emergence of alternative methods such as green burial and resomation. In this competitive market, funeral service providers are forced to inform the public more convincingly about their offers and distinguish themselves based on a variety of factors. Technologically, deathcare methods need to satisfy fundamental provisions of the client's belief-system, which determines whether a corpse must be preserved or it can disintegrate. Environmental concerns and facts weigh in in support of science. Finally, economics can link both aspects in terms of their value.

The cost of a method reaches beyond the technology itself but also include preparation such as embalming for viewing and other ceremonial garnishes such as caskets and shrouds, or the land required for a final resting place. Deathcare is largely privatized in the US, where state and church hardly assume responsibility of dealing with the deceased. Nevertheless, legislation can make or break significant changes to the market, as is currently the case with the legalisation of resomation at state level. Alternative organization types such as 'not-for-profit' or 'co-operatives' increase the diversification in the market and offer the consumer more choice along the fine line business and deathcare. The largest funeral provider in the Netherlands, Yarden, also a non-profit, positions itself on the forefront of industry development by commissioning research, driving technology innovation, pushing for legal opportunity and including shadow costs, which express the efforts necessary to remediate or avoid environmental impacts.

Death, however, is not an intentional expenditure. High costs are inflicted on mourners not only because of the technical necessities, but also because the deceased should be honoured appropriately with symbolic ceremonies and rituals. As mentioned above, these are often still deeply rooted in cultural-religious norms. Funeral poverty is an increasingly frequent occurrence, especially among the working class and elderly. The things humans have in common in death stop short of affordability. Here, the argument is to grant the deceased dignity, regardless of economic, environmental or cultural status and disposition. Sliding scales for prices can be based on shadow costs, but with little relief for the economically weak.

A fair-pricing model, as proposed by the UDP, would convert the economic disparity into social sustainability, where the well-off pay the highest rate to offset negative margins for people who cannot afford the most basic of deathcare. For this to work, however, a more complete vision the income levels of potential customers is necessary. The concept of fair-pricing can apply to the local community as well as beyond, although it will be a challenge to convince potential clients without significant place attachment. However, Seattle's demographics present an opportunity with one of its fastest growing age-group being the above-55 year olds. Young adults, the largest age group in Seattle, show the highest rate of residential mobility, which may hamper their commitment to UPD's vision of weaving 'the cycles of life into the urban fabric', significantly reducing the target market.

From an environmental point of view, the UDP translates the emerging green burial movement into an urban setting. The industrial application of natural decomposition is environmentally attractive, although the need to occupy scarce urban land may be a point of contention. Without the envisioned remembrance gardens surrounding the facility, the distinction from cremation and resomation as well as the green-burial appeal would likely be perceived as too weak. This is where the inclusion of environmental cost can make a difference, particularly if recomposition can utilize urban waste streams such as garden clippings and organic kitchen waste, and if the material output can avoid the sourcing of a comparable product. Both potential benefits can directly reduce cost to the funeral client.

Other than financial obligations, spiritual norms largely determine funeral methods. A majority of Seattleites follows Christian conventions, in which blessed grounds are essential for a religious funeral. This aspect may be challenging to honour in the recomposition process, where every corpse traverses the same facility. However, since cremation is accepted, the availability of designated grounds for the compost may be the only barrier. The high portion of non-religious residents represents an opportunity for recomposition as a holistic method, appealing to rational groups such as atheists and agnostics. Nevertheless, Buddhists and Hindus, non-orthodox Jews and modern Christians are also concerned with environmental effects of deathcare. Seattleites attribute each other with open-mindedness which should be interpreted as an opportunity for the UDP.

Finally, legalization of novel deathcare methods has recently seen a lot of activity across the United States due to the commercialization of the alkaline-hydrolysis technology (resomation). This incurred resistance from the Church in several instances, which mainly took aim at the processing and disposal of remains. However, recomposition can be interpreted as a thermal, flameless 'cremation by carbon', which is common practice in livestock disposal. The natural process of decay seems unlikely to experience objection from religious and legislative authorities, as long as the dignity of humans and the health of the environment are honoured.

4.2 The Environmental Impacts of Dying

There are several inherent problems with the current deathcare system in the United States. Some of these problems have physical elements to them, such as the harmful materials used in the embalming process, the over-materialization related to the funeral ceremony and the overcrowding of cemeteries due to eternal burial. Although these aspects seem unrelated, a new, innovative funeral technology could take this into consideration and design a system that improves in all areas. As the conducted research on emissions, LCA and land use of different funeral technologies has revealed, recomposition could offer a possible solution to these problems. In this section, the environmental impacts of the main phases of deathcare are analyzed and discussed in a chronological order. The aim is to present a complete environmental profile for all the technologies under study.

In this study, we looked at aspects that directly related to the respectful and safe disposal of one human body. It is important to note that that surrounding activities such as mourning correspondence, flower cultivation, food and beverage production and visitor transport can make up to 75-95% of the total environmental impacts of a funeral. It is therefore crucial to always consider the funeral in a system perspective. Furthermore, compared to other activities during a person's life (and death), the absolute environmental impacts of the funeral are found to be quite small, which adds some nuance to the importance to the results. Nonetheless, there is a lot of room for improvement in the current funeral industry and some practices (unnecessarily) cause substantial damage to the environment.

4.2.1 Preparation of the body and funeral

Before the body is admitted to its final place on this Earth, be it the grave, oven or other facility, a few practices are common in the US. Firstly, if relatives desire to have the body on display before the funeral, embalming is mandatory. Embalming, the process of preserving the body by decreasing the speed of natural decomposition, has been an important aspect of the American deathcare since the civil war. Embalming fluids are notorious for the use of formaldehyde and other toxic chemicals that have large environmental impacts. Embalming is required by law if the body is to be prepared for a viewing ceremony, but there are ways to circumvent this by skipping that ceremony entirely. The green burial movement already utilizes less toxic embalming alternatives. Introducing these alternatives in the dominant funeral technologies would reduce their overall environmental impacts. Although not preferred over not applying embalming at all, it could also be a last resort for the UDP in case adapting the legislation proves unsuccessful.

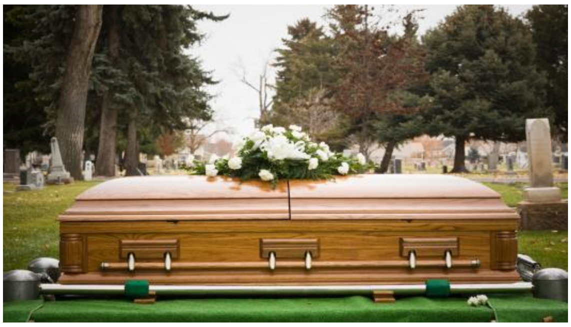


Figure 9: A commonly used wooden casket (Today, n.d.)

Secondly, almost without exception, the body lies in a coffin. These range from simple coffins from untreated wood or willow branches (especially used in green burial) to extravagantly ornamented coffins with veneer, lacquered finish, satin lining and metal ornaments. Obviously, the environmental impacts of producing and burying luxurious coffins are higher and are actually found to be one of the main hotspots of the total footprint of the funeral. With the rise of cremation also came a different role for the coffin: It is used for display purposes only and the body is burned in a cardboard coffin. This is one point where cremation practice in the US is more sustainable than in the Netherlands. In recomposition, it is likely that the coffin will fulfil a similar viewing role. How often the coffin is rented and the way in which it is recycled or disposed of is an important determinant of the environmental performance of the funeral technology.

Thirdly, a body is often wrapped in a shroud. While this only has limited mass, choosing a conventionally cultivated cotton shroud (the same can be said for the coffin lining) has a remarkably high contribution to the total footprint of the funeral. This is mainly because conventional cotton cultivation is quite resource intensive and heavy doses of pesticides are added in the field. Therefore, a very simple but effective way to improve environmental performance would be to look for more sustainable alternatives here, like organic cotton or hemp.

Fourthly, some of the funeral methods entail the placement a monument or storage of remains in an urn. These both have high associated impacts, depending on the type and quantity of materials used. One example of an unsustainable option would be the use of a heavy brass urn that is buried in the ground.

As was learned through interviews with experts, the largest environmental impact of a funeral and its related processes is the required commuting for people attending the ceremony.

4.2.2 The process

The method of disposal, to put it crudely, differs enormously between the technologies and it is therefore hard to compare them on an equal basis. The analysis made in this report is based on many assumptions of the system's parameters and although it is aimed to look at the most average situation, reality is just not always average. Every funeral technology has its own associated environmental problems and its own areas for improvement. There is no one sustainable funeral technology, because if this one technology would be all there is on the market, the environmental problems of that technology would become emphasised. Therefore, both increasing process efficiency of each of the technologies and increasing diversity of options in the market are desirable developments. That being said, there are some conclusions to be drawn about each of the technologies.

The process of burying the body is quite an environmentally friendly one, if done right. It is mostly composed of the digging and closing of the grave. However, one serious issue with the burial process in the US is the frequent use of a burial vault, a reinforced concrete lining in the grave, before it is covered with soil. This, combined with extravagant coffins, makes burial in part a landfill for durable and valuable materials that are never recycled. In green burial, these are the parts of the process that are improved and that increases the environmental performance tremendously. For cremation, the main issues are with energy use and flue gases. It uses large amounts of (fossil) natural gas and it therefore has a relatively high contribution to climate change. Furthermore, it needs heavy duty flue gas cleaning installations to clean the air up to the standards of an (often densely populated) urban environment. However, the practice of burning the coffin in a cardboard box is a huge process improvement compared to the Netherlands and cremation is therefore not found to perform much worse than other funeral technologies. Resomation is quite new on the market and is promoted as a more environmentally friendly alternative to cremation and burial. In this study, it was found to indeed have lower associated environmental impacts. However, due to the relatively good performance of cremation, the differences are small. The main public concern, being the chemicals used in the process, do not seem to be the biggest environmental problem. Since resomation uses a lot of electricity, the source of this electricity is an important parameter.

Recomposition is different from the other funeral methods in that it provides more than one function. Where the other processes are designed to safely dispose of one human body and produce nothing but wastes or emissions alongside, recomposition also produces around 500 kg of compost. The process uses around a ton of additional biomass (currently wood chips and alfalfa mix) to recompose one average 70 kg human body. This immediately touches upon one of the two largest contributors to recomposition's environmental impact. The first are the emissions related to the composting process itself. In the composting process, microorganisms release a large amount of gases. Among the most problematic are methane, ammonia, nitrogen oxides and dinitrogen monoxide. These gases contribute to climate change, particulate matter, acidification and marine eutrophication. In these areas, recomposition performs worse than most of it competitors. Especially particulate matter formation can be seen as a problem in an urban context. Furthermore, the cultivation of this amount of biomass, assumed to take place outside of the city, has high associated environmental impacts. Depending on the type of cultivation (organic, intensive, or extensive), the types of impact differ but range from agricultural land use, water use, overfertilization, pesticide use and to a lesser extent its transport into the city. It is very important to the environmental performance of the recomposition system to choose a sustainable source.

Figure 10: Recomposition process's end product - compost (Agrea, n.d.)

Ideally, waste biomass from the municipality of Seattle is used in the process, killing two birds with one stone. Recomposition then becomes a multifunctional process: Upcycling municipal biowaste, producing compost (therefore also avoiding production of compost in another facility) and of course respectfully providing a last resting place for a person. It might seem crude and technical to look at it this way, but it is actually a holistic view. A sustainable world is organized in networks, just like nature. It is full of symbioses and interconnections to make optimal use of energy and resources. By looking at the recomposition process as a multifunctional one, the environmental impacts can be attributed to the various functions. Recomposition has relatively high impacts due to the sheer quantity of biomass used and the emissions produced in the composting process. However, considering recomposition as a multifunctional system reveals a sustainable picture.

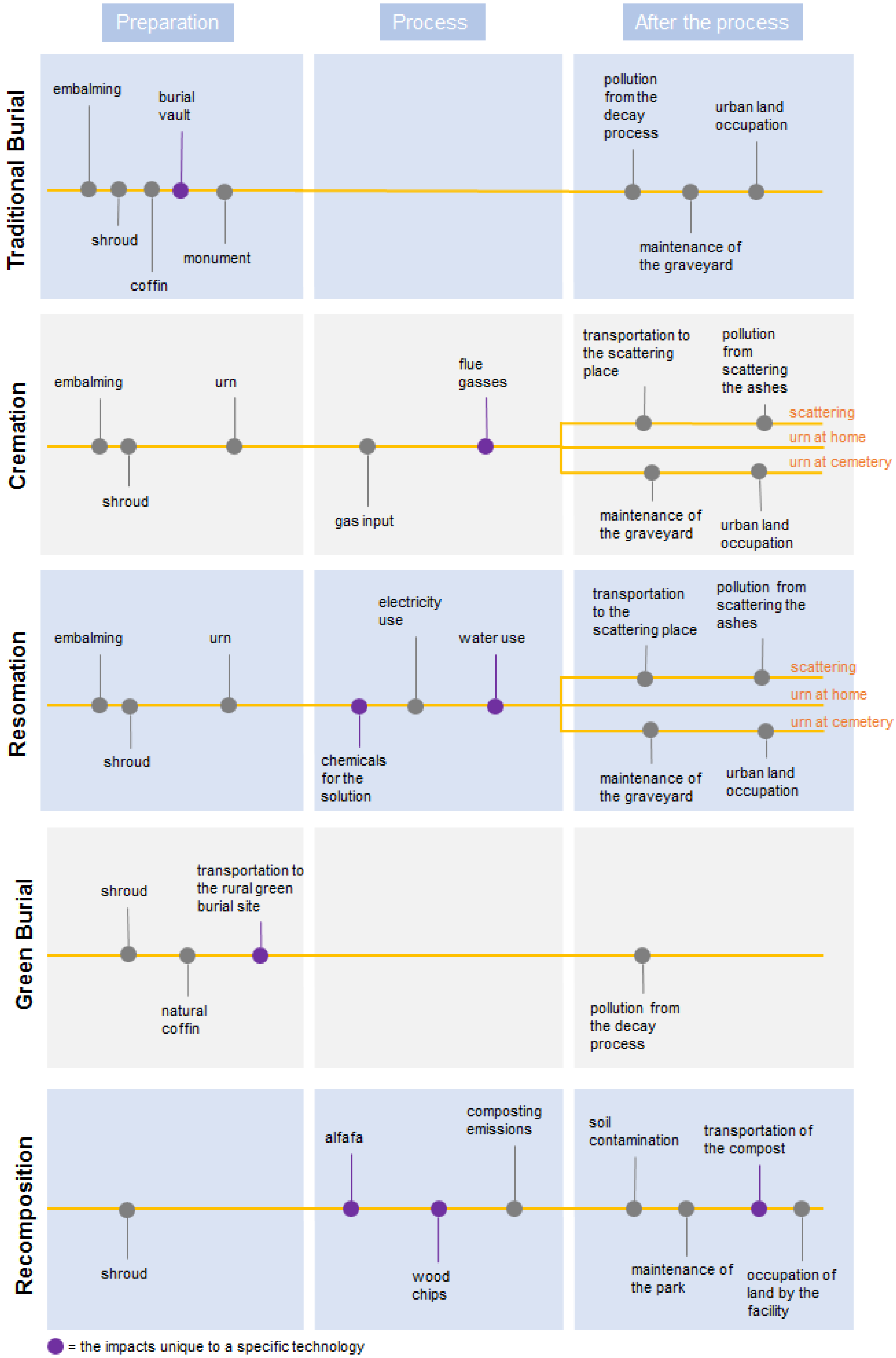
4.2.3 Impact after the process

The most notable environmental impact of traditional burial that occurs after the process is land use. As stated before, in the US the practice is to bury someone for an eternity. The overcrowding of cemeteries in Seattle is one of the reasons that UDP was realized in the first place. But why is extensive land use exactly a problem?

Any land occupation by urban settlement, or agriculture for instance, can be seen as having a negative environmental impact, as it diminishes the amount of natural land available. The natural land, being it a forest, swamp or a meadow, helps to maintain important ecosystem services and ties down CO2. Without a doubt, in a densely populated urban metropolitan area such as Seattle, natural land is already difficult (if not impossible) to find. However, an extensive land use by funeral technologies results in a need to expand the city further in order to meet other needs of the urban settlers such as housing.

Green burial requires almost twice as much of land as traditional burial. This is due to the fact that the bodies need to be further apart in order for the nutrients to permeate. The eternal burial practice in the US, together with the ever-growing green movement, has resulted in a phenomena of creating green burial sites with the purpose of preserving nature. As an example, The Green Burial Council (n.d.) of the US states on their website that one of the aspects leading them to establish a green burial site, which later developed to the Green Burial Council, was the desire to protect the surrounding nature. Therefore, one can actually argue that land use by green burial practices will eventually have a positive environmental impact on the society as they promote nature preservation.

Figure 11: The occurrence of the main environmental impacts of the five funeral technologies



What is characteristic for the UDP is the idea of not developing solely what is a cemetery, but also a natural park for the community. Serving multiple purposes means that the facility is multifunctional, and consequently one could state that due to this multi-functionality an Urban Death Center would be more valuable for the community than a traditional cemetery. Cremation and resomation require approximately the same amount of land as recomposition, but yet again the cemeteries fail to serve other purposes than a memorial site for the community, besides increasing biodiversity naturally. To conclude, for an urban area, recomposition would result in the most efficient use of land, when considering the extent together with attributes of the land occupation.

Figure 12: Crowded cemetery in Queens, New York (Wikipedia, n.d.)

Another consequence of providing an eternal resting place is that the cemetery will have to be maintained for eternity as well. The most noteworthy resources for maintenance are fuel, water and plant seeds. Accumulating over many years, the environmental impacts of this can be discernible.

It is important to note that regardless of the applied funeral technology, there will always be emissions to the environment (long) after the body has been processed. The body will naturally decompose over time in the case of traditional and green burial, resulting in emissions to the local environment. Remains of the cremation and resomation can be taken far away to a special location to be scattered there, impacting the environment of that specific location.

4.3 SWOT analysis of recomposition

Based on the researched literature, conducted studies, expert knowledge and current events, the main strengths, weaknesses, opportunities and threats of the UDP were identified (see Figure 13). The strengths and weaknesses are internal factors whereas opportunities and threats external. In the diagram below, the complete list of identified SWOT's is presented. Afterwards, the SWOT's that have not been discussed prior to this chapter are elaborated more in details.

4.3.1 Strengths

The UDP shows to have a good media outreach. The Ted-talks held by its founder Katrina Spade, and the fact that researchers in the field from different countries are aware of recomposition and doing research on it drives the general awareness. This partly contributes to the broad network of experts. The organization includes members of the funeral industries, research institutes and universities. Furthermore, UDP works in collaboration with independent researchers and universities to study recomposition processes.

Since recomposition does not include placement of remains as the remains are scattered rather than buried, there is no cumulative impact (of remains buried) involved in recomposition. Another strength to recomposition is the circular design of the process. The UDP applies circular economy principles to the bodies which make humans, especially their death, part of the circle of nature. The fact that the UDP is a non-profit organization complements their goal in involving society more in deathcare. As non-profit organizations are generally known for their positive community involvement this is a real strength. The fair-pricing model contributes to this as well. By making people pay according to their income level, more cross-societal awareness is created.

Figure 13: SWOT factors of recomposition as proposed by the UDP

4.3.2 Weaknesses

Since the UDP is focused on implementing recomposition practices in Seattle first, questions remain to which level their idea of the implementation of recomposition is scalable to other states in the US. Since the religious make-up of Seattle is quite different to other cities in the US their current concept might not be so well received there. Furthermore, question is whether the amount of land that is required when implementing recomposition on a large scale is available within cities. Adding to that, more biomass will be needed, which puts pressure on the demand for biomass and therefore land use for crops.

As highlighted multiple time in this report the concept of recomposition and the actual implementation of it in Seattle is rather underdeveloped. This means that there's only limited information available which results in a rather unsure future outlook for the UDP. Another weakness of the concept of recomposition as introduced by the UDP is the limited throughput. In the current concept 52 bodies could be recomposed per facility, which is a small fraction of the total amount of people that die each year in Seattle. Finally, as the UDP is a non-profit organization it is dependent on the grants of donors. This can provide for difficulties in the implementation of recomposition since budget might be small.

4.3.3 Opportunities

The pressing concern over climate change, both among individual consumers as well as the government, could offer an opportunity for UDP to expand. Moreover, as the amount of non-affiliated in Seattle demonstrates, the area has a progressive culture that easily embraces new innovations. During the past decade, Seattle has emerged as a technological-hub of the West Coast, scoring as third largest tech-talent market of North America in 2016 according to CBRE (n.d.).

Recomposition is a new and innovative funeral technology, however it is not the sole pioneer on this field. The current push of resomation as an alternative funeral method can be a legal and social ice-breaker for recomposition. Especially in legal context, it drives exploration and modification of state laws regarding deathcare from which recomposition might benefit (Tekle, 2016). Furthermore, it may increase public susceptibility towards innovative forms of deathcare.

4.3.4 Threats

The composting of human remains might be difficult to accept for the whole society. The more well-known and advocated such an alternative technology becomes, the more resistance it might face. Deathcare is a sensitive topic and if not handled with care, UDP could even face a public outrage.

UDP's main objective is to offer sustainable, affordable and graceful alternative to deathcare. It is, however, not the only start-up working on such a solution. Resomation for example as mentioned before, also markets tself as an sustainable alternative. Other innovations such as the mushroom suit by Coeio (n.d.) or the tree capsules by Capsula Mundi (n.d.) are seeking market share, which might negatively affect the number of people opting for recomposition.

Since January 2017 the new president of the US, Donald Trump, has made it clear that environmental protection and climate change mitigation are no longer essential parts of US federal policy. Announcement to withdraw from the Paris Climate Agreement on the June 1st confirmed this course (The New York Times, 2017). Weak environmental policy can affect for instance the grants and governmental assistance available for sustainable innovations, thus forming a threat to the UDP.

4.4 Recomposition in modern society

This study attempts to address several factors which will be relevant for the development of recomposition as a deathcare alternative. Five focus areas were identified, each of which respond to individual elements of the main research question: "From the point of environmental impact and social context, can recomposition be a viable alternative to traditional burial, green burial, cremation and resomation in an urban setting?".

The short answer is yes, as recomposition seems to present compelling arguments to a receptive audience at the right time.

The marketplace of alternative funeral methods is getting more diverse and environmental performance is increasingly considered to be an important factor, in which recomposition compares favorably to established and other novel funeral methods. Additionally, recomposition is expected to become available at a competitive cost. The UDP is based in the progressively-minded Seattle, which leads to higher levels of social acceptance with regards to innovative funeral technologies compared to the rest of the US. Recomposition's holistic nature and proposed fair pricing model can add a fresh and desirable dimension to the current funeral industry. Indications are that many of the more conservative (religious) groups in the area are also open towards recomposition. However, when aiming to offer recomposition beyond Seattle, one needs to keep in mind that perceptions, motivations and responses can be significantly different. For the UDP, the challenge lies therefore in strong branding and marketing.

In terms of environmental impact, recomposition performs very well in exactly those areas where current methods show weaknesses. With regards to land use, the renewable capacity of recomposition has an obvious advantage over other technologies, especially traditional and green burial. However, all depends on how the technology and UDP's business will develop. It is essential to perceive the wider system within which the technology is embedded. The associated environmental impacts of recomposition are comparatively high because of the large quantities of additional required biomass. However, it is fundamentally different from other funeral methods because it provides multiple functions: The provision of a green space in an urban setting, (potentially) upcycling urban biowaste, producing compost and of course respectful disposal of the dead. Through collaborations with partners who benefit from these functions, the UDP can significantly increase recomposition's environmental advantage over other deathcare technologies. Furthermore, by including shadow costs, the UDP can increase awareness of the environmental impact involved in deathcare in general, potentially affecting the whole industry.

In the context of other human activities, the environmental impact of the singular occasion of one's deathcare is negligible. Further, within the wider event of a funeral, the effects of the human body, regardless of disposal method, are almost irrelevant compared to auxiliary activities such as the family's impact from travelling to and from the ceremony, reception, etc. Nonetheless, reducing the environmental impact of deathcare brings us one step closer to a more sustainable world. This is particularly true in an urban setting where environmental stakes are high.

The limitation of research at this stage of system development is that available information about process specifications, societal context, costs and consumer perception is incomplete or derived. However, an advantage is that a truly sustainable system can be developed surrounding recomposition from scratch. Or, in industrial ecology terminology, a system can be created where energy, resources and social and economic value are kept at the highest possible level. The UDP can form symbioses with actors in the local community and become part of an efficient and sustainable design of a circular society.

Figure 14: The skyline of Seattle (TripAdvisor, n.d.)

Chapter 5 What's next?

The final chapter of the consultancy report identifies the main knowledge gaps, weaknesses and other practicalities of this study that need to be resolved. The identified aspects can serve as a checklist for the UDP to add new focus points to their own research. These recommendations are subdivided into two categories: research and collaborations.

5.1 Research

This study has revealed a lack of viable primary data. The economic and socio-cultural assessments are based on few data points and would benefit from greater quantities of data. Qualitatively, future research could segment the population by age rather than religion. Additionally, a more detailed analysis on what factors influence people's decision of a funeral method could shed more light on what the UDP should focus on in their concept. When reviewing the proposed concept of fair-pricing, a detailed market study, regarding incomes of people interested in recomposition, and a study into a way of dividing the costs for recomposition over the income classes is advised. The need to further develop the concept is already stressed in the SWOT analysis. This also entails that a definite price needs to be set for recomposition, which requires more research into its processing costs. Here, shadow cost have the potential to become more important if they accurately reflect people's perception of types of cost incurred by environmental impact.

The modelling decisions for the LCA and land-use studies are based on low-quality information and significantly depend on proxies or assumptions. Although current LCA tools may not afford more specific modelling choices based on available databases, some aspects of material inputs and conversions can become more precise. In terms of land-use models, further scenario development can reflect the strategies of planning authorities, regulatory limitations, expected social acceptance, economic feasibility and organisation management in many different configurations.

Another interesting topic for research is the idea of recomposition facilities on top of buildings as an alternative to green roofs, although this has not been addressed in this report. Another recommendation is to examine how the spread of pathogens can be reduced and the process speed increased as a way to further industrialize the process. Since recomposition can take place in a closed system and the UDP has full control over its input and output flows, it would be interesting to look into emission filters to reduce emissions further. From a regulatory perspective, in case the compost output of recomposition will not be identified as a good, there may be a possibility of mixing the output soil with generic soil. By reducing the concentration of 'UDP compost' in a given quantity of soil, it might be able to pass through the legislation. This would of course be far from the ideal scenario, but being able to allocate the production of compost would decrease the environmental impacts of recomposition significantly.

5.2 Collaborations

More collaboration with other stakeholders might lead to increased insight for the UDP to develop their concept. The insurance providers, notaries for wills and mourners can provide more knowledge on the demand side of deathcare. Increased collaboration with Western Carolina University can help to identify emissions to the soil and air from human bodies in recomposition. Contact with local or regional bio-waste producers might open up an opportunity to use garden clippings or kitchen waste instead of alfalfa. Furthermore, a partnership with the Columbia University Death Lab (NY) can help to expand knowledge regarding recomposition processes. Finally, close ties to governmental organizations and lawmakers might increase the likelihood of the process output being classified as a good and to legalize all processes related to recomposition. Beyond these immediately relevant benefits, collaborations with all stakeholders may trigger developments in the wider deathcare landscape and initiate further benefits for the UDP.

Figure 15: Greenery is welcome to Seattle (Patano Studio Architecture)

SCIENTIFIC REPORT

Chapter 6 About the report

In the scientific report the different research questions will be answered in five separate research reports. The scientific report will serve as a scientific foundation for the information in the consultancy report. These sections will help in answering the main research question:

From the point of environmental impact and socio-economic context, can Recomposition be a viable alternative to traditional burial, cremation, green burial and resomation in an urban setting?

For a short overview, below the individual research questions are provided that subdivide the main research question.

Socio-cultural analysis
What is the level of social acceptance of new funeral technologies among different sub-communities?

Economic analysis
Does the economic context serve as a driver or barrier for the development of recomposition?

Land use modelling
What can land use models tell us about differences in potential land use impacts of the technologies?

Emissions to the environment
What are the emissions (to soil, groundwater and air) that can be expected during the compositing of human remains?

Comparative Life Cycle Assessment
What can a comparative LCA study of funeral technologies tell us about life cycle impacts?

Chapter 7 Socio-cultural analysis

This chapter seeks to comprehensively inform the UDP and its stakeholders about society's perceptions, opinions and responses to deathcare in general and recomposition in particular in the Seattle Metropolitan region and beyond. Subsequently, the question *'What is the level of social acceptance among different sub-communities*?' will be answered. The nature of these topics determine the findings to be mostly qualitative, although the applied methods also allow quantitative analysis in parts.

7.1 Introduction

Among the many unanswered questions surrounding recomposition, some of the most difficult to answer will certainly aim at the social context. How will the general public perceive and accept this new concept? Is UDP's proposal acceptable to the funerary party? Are people interested in new methods in general? What are the drivers and barriers in the decision-making process of mourners or people planning their own funeral? Several researchers have attempted to shed some more light on understanding the social context of funeral practices. For any organization that provides services or products, it is important to know the motivations of its target group, in order to become more successful. This is at the core of the field of market research and particularly relevant for start-ups such as the UDP.

Rather than approaching the so-called 'new' funeral practices such as green burial from a general standpoint, it is important to respect the locally and regionally embedded practices and cultural landscapes of locations, as argued by Marshall & Rounds (2011) with regards to transitions in the funeral industry in Australia. American writer and scholar, Suzanne Kelly, forms a compelling argument for a revised approach to funeral practices in the US, by calling for breaking with the taboo of death and decay in favor of environmental sustainability value (Rumble, 2017). This benefit is also highlighted by Marshall & Rounds (2011) with regards to land-use. In the US specifically, environmentally sensible methods are historically embedded, since the Native American population's burial traditions entail shallow graves or intentional exposure to the elements and wildlife (National Park Service, n.d.). The dimension of cemeteries' function of cultural integration seems particularly relevant in a country founded by migrants.

McClymont, 2016 raises conflicts surrounding the functions of urban cemeteries such as personal place attachment (individual, emotional values and meaning) vs greenspace (biodiversity and public arena). In similar opposition, Reimers (1999) concludes that the rupturing event of death in a community can lead to either communal/integrative or individual/differentiating methods of deathcare, which Wilson & Chiveralls (2013) argue is largely based on a reaction of convenience at time of emotional turmoil. Grief also forms a major obstacle for obtaining reliable information when it comes to personal dispositions with regards to funeral practices (Halpenny, 2013; Palgi & Abramovitch, 1984).

Finally, Crabtree (2010) finds that increasing individualization, breaking with traditional elements of deathcare, and acceptance of non-physical aspects in funerary practices are strongly on the rise.

This range of factors and the general nature of available research highlight the necessity to conduct a more specific assessment of the UDP's target group in socio-cultural, spatial and environmental contexts.

7.2 Methods

The UDP's mission faces a multitude of challenges arising from a heavily competitive deathcare industry, distinctive local lifestyles/norms as well as limitations of insight, whether it is already existing or yet to be gained. To that end, a survey has been selected as preferred method to collect primary data from the UDP's priority target region of metropolitan Seattle. The region is divided into council districts, resulting in 7 areas of sample collection.

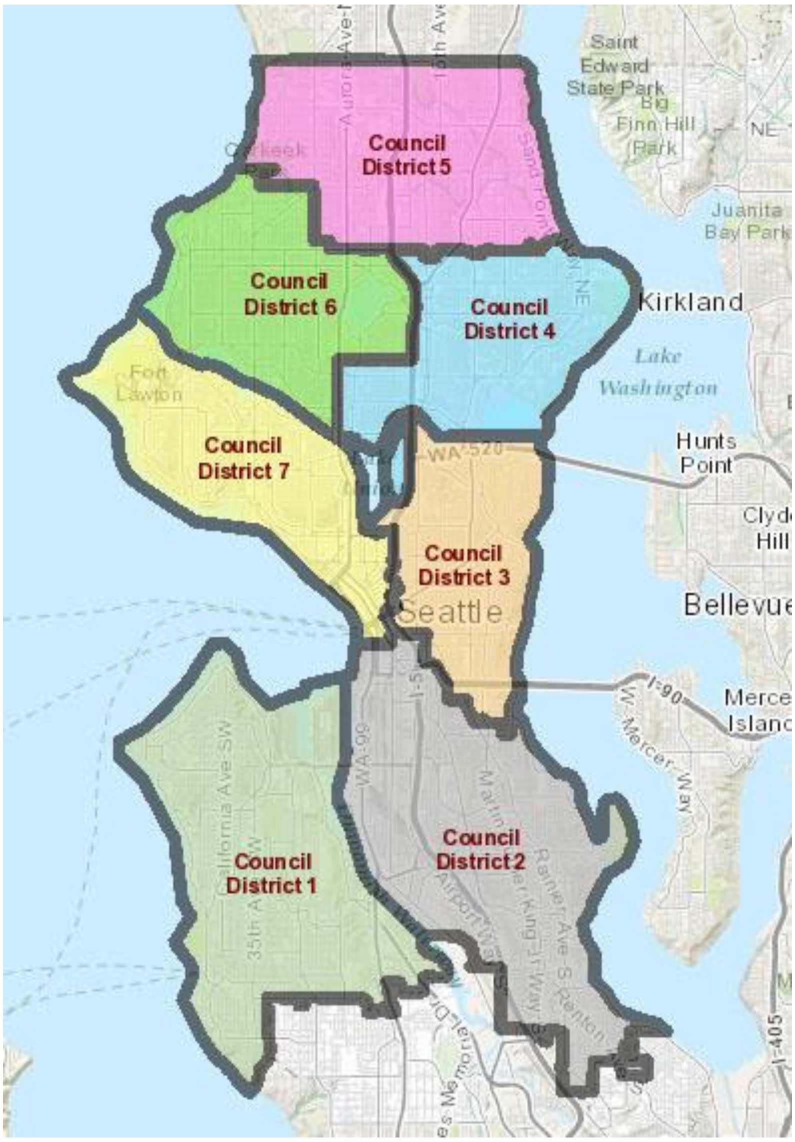


Figure 16: Seattle Council Districts (Office of the City Clerk, 2017)

The survey is generated in two versions: for religious community groups and for funeral homes. Both groups are directly involved with the organization of funerals, although their motivations for and perceptions of specific stages in deathcare can be fundamentally different. Further, the UDP is aiming to become part of the funeral industry, which will make insight from potential competitors valuable.
The segmentation of the population follows the assumption that funeral rites are historically associated with religious belief systems. Based on aggregated research results from Pew Research Center (2017a, 2017b) the selected religious groups for this project are:

- Protestant (Presbyterian)
- Catholic

- Atheist/agnostic/unaffiliated
- Hindu
- Buddhist
- Jewish
- Muslim

Table 4: Religious composition of adults in the Seattle metro area (Pew Research Center, 2017a)

Faith group	Religious denomination	Population share [%]
Christian	Protestant (aggregated)	34
	Catholic	15
	Other	3
Non-Christian	Jewish	1
	Muslim	<1
	Buddhist	2
	Hindu	2
	Other	4
Unaffiliated	Atheist	10
	Agnostic	6
	Other	23

Representatives for each community within each council district were found on their group's website. Where this wasn't possible for the selected areas, contacts from the wider Seattle region were accepted in order to provide a sufficient and equal number of participants. In case of some atheist/agnostic organizations, contact was only possible through the online platform meetup.com. Contact details for funeral homes from each area were also collected online.

The survey is structured in two parts. First, the respondent is questioned about their community's/industry's behaviours, motivations and reasoning with regards to deathcare. The second part specifically investigates the community's/industry's potential response to the novel method of recomposition. Two versions of the survey contain 14 to 17 questions for the religious groups and funeral homes respectively. In order to accommodate the religious/spiritual and economic contexts of the target groups, some questions are adjusted or entirely different.

In addition to the survey, literature research supports the critical assessment of the survey and expands upon its results. The journal 'Mortality' has been a significant resource in this case. While the survey addresses the population of Seattle specifically, most of the literature used in this report is also based on primary data from other countries such as the UK.
Finally, several informal interviews were conducted with stakeholders of the funeral industry in the Netherlands. These mainly serve to verify and expand upon some of the trends highlighted in literature.

As already stated in the introduction of this chapter, the way people deal with death and the deceased is distinct in each location or region. The survey has therefore priority over the more general literature and the Netherlands-specific interviews.

7.3 Results

7.3.1 Religious

One response from the religious groups was not allocated but can be associated to the Christian/Catholic faith based on the mention of Canon Law. There was no response from the Muslim community. Single responses returned from the Jewish, Buddhist, Hindu and Atheist groups. In total, 6 respondents engaged in the survey, most them with direct roles in the funeral activities within their community by means of counseling or mentoring mourners, making arrangements or presiding over funeral services.

Deathcare is found to be no taboo topic among community members (Appendix A.1 - questions 3). Discussions happen frequently or at least sometimes and in most groups on a routine basis as part of regular sermons, specific religious holidays or during workshops. The most common factors in choosing a funeral method tend to be of a social or practical nature, while family traditions, financial burdens and environmental impact occasionally take priority depending on religious context. There is no indication that any single factor is the ultimate driver. Complementing this observation is the fact that all types of support within all groups are high, with the exception of a catholic respondent citing a lack of financial support. With 83% of the respondents, the majority attributed low importance to living near the grave/urn/scatter grounds of their deceased relatives. ⅝ of funerals tend to be cremations and ⅜ still follow the traditional burial. Similarly, single answer responses are split 2:1 in favor of cremation over burial. The discussions within communities about different methods follow the same pattern, although this does not lead to a clear result with regards to how well people are informed about methods in general. However, the respondents attest their communities a relative openness towards discussing novel methods. This is confirmed by the respondents' perceived acceptance of recomposition being high, with the exception of a catholic group. Canon Law is cited as the most significant barrier, which is deeply engrained in authorities' traditional positions. Interestingly, a financial incentive of significantly lower cost does not trigger notably different responses (Appendix A.1 - question 13).

7.3.2 Funeral industry

There was only 1 response out of 6 survey recipients. According to this respondent, discussions about deathcare only happen occasionally outside of funeral homes. He attests average knowledge about traditional burial and cremation, while green burial, resomation and cryomation are largely unknown to his clients. Preferences for deathcare methods tend to be strong, which seem mostly driven by financial, social and religious expectations and constraints. Environmental considerations are mostly disregarded and time constraints are only somewhat relevant. Both aspects of strong preferences and decision drivers confirm the respondent's judgement that there is only a limited likelihood of people considering methods other than the mainstream ones. Alternatives may have the best chances if appealing to environmental or financial choices, where financial aspects are clearly largely unknown to clients. This assumption is complemented by the observation that clients regularly experience unforeseen financial burdens as a result of their funeral choice.

The respondent expresses a high desire among their clients for close proximity to the resting place of the deceased. Finally, their clients' familiarity with traditional burial and cremation does not oppose a relative openness to discussing novel or alternative methods. From an industry perspective, this discussion could be elevated through trade publications and anecdotal conversations with peers.
Specifically asked about recomposition, the respondent is somewhat confident that the method will find acceptance, while they are 'absolutely' interested in offering this method when it becomes available. While the respondent expects to see the funeral industry mostly responsible for carrying out the technological aspect of funerals only, they acknowledge the complexity of funerals and their industry but is not tempted to draw any conclusions as to how recomposition may fit into this industry in the future.

7.4 Discussion and Conclusion

7.4.1 Spectrum of results

Both surveys have covered almost identical content and provided insight from the perspectives of the two most significant actor groups in the context of funerals: clients and service providers.
The questions about relevance of factors regarding decision-making provides a good overview of standpoints and allows direct comparison of responses. Here, the response from the service provider (Figure 18) is a surprisingly good representation of the aggregated feedback across all religious groups (Figure 17). Financial implications is a significant driver of decision-making, while religious motivations and societal expectations also frequently rank at least average. Despite the high ranking of financial aspects, the funeral director indicates that most people are under- or ill-informed when it comes to the cost of a funeral (Appendix A.2 - questions 8 & 9). However, comparing the responses from the religious groups in more detail, there is no obvious trend in terms of common priorities.

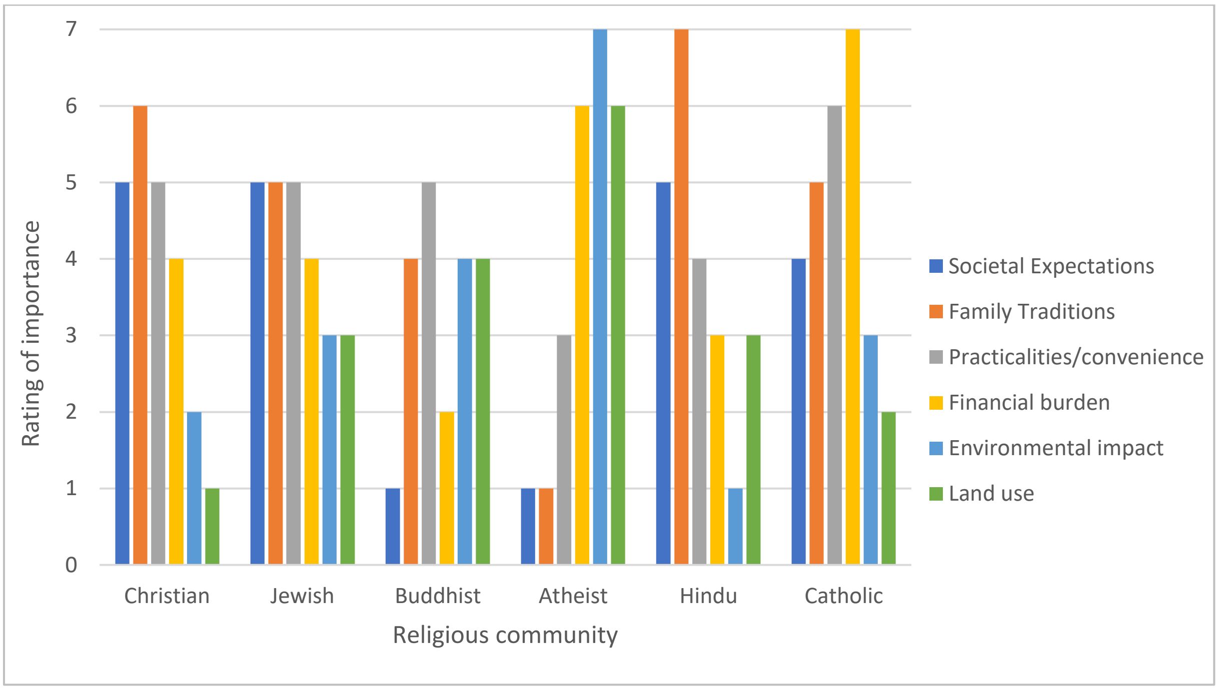


Figure 17: Religious survey question 4, summarized result

At other points, there are clear discrepancies between the two groups. Importance of proximity to final resting place is ranked across the spectrum but bottom-heavy by the religious respondents. The funeral director attributes a high value.

A similar result is seen when questioned about the perceived openness of Seattle's inhabitants to new deathcare methods (Appendix A.1 – question 10; Appendix A.2 – question 12). The reverse is the case with regards to perceived acceptance of recomposition in particular among Seattle's population - the funeral director is less optimistic (Appendix A.2 – question 14), while religious groups are split at either end of the spectrum but top-heavy (Appendix A.1 – question 11).

What can be learned from these results is that the perception of both survey groups can be very different when asked about the same topic. It confirms that the parties operate with different information (Halpenny, 2013).

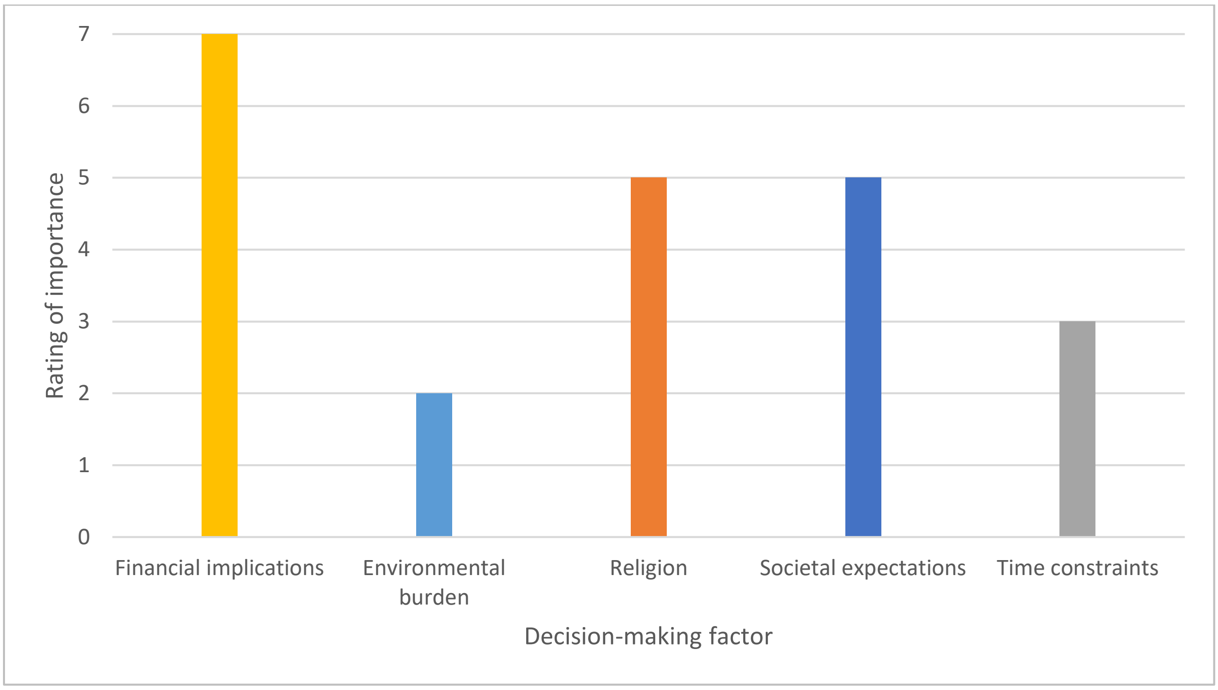


Figure 18: Industry survey question 5, summarized result

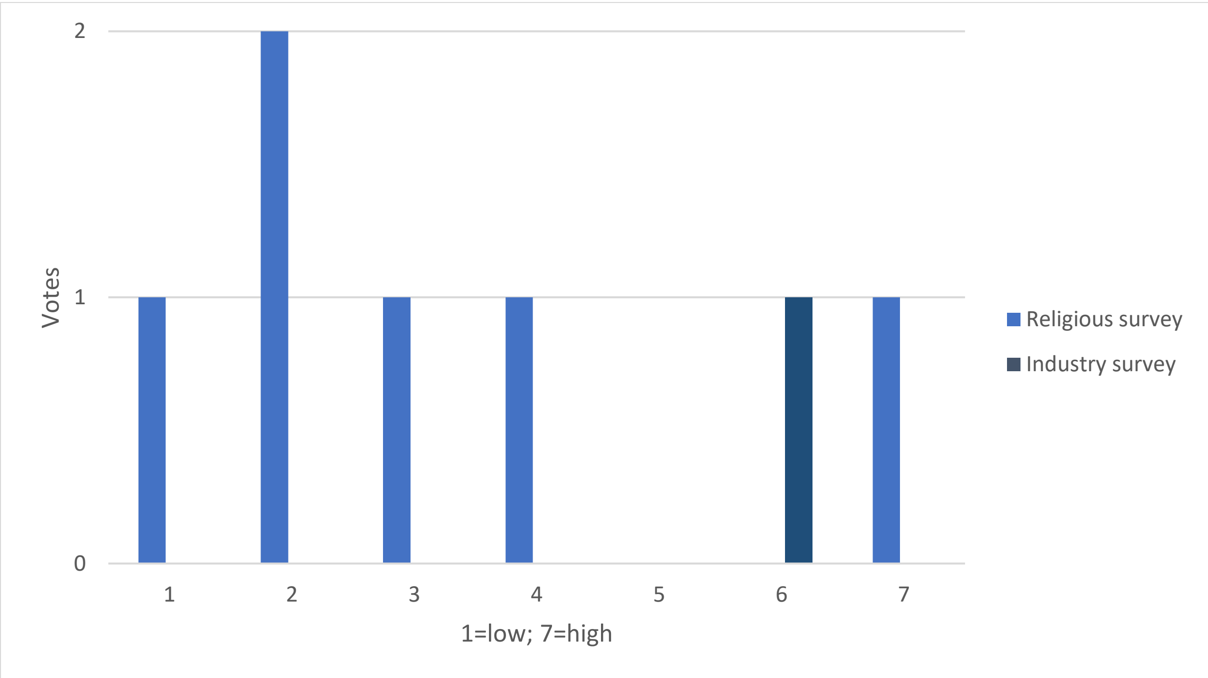


Figure 19: Importance of proximity to the final resting place of the deceased

Another significant contrast, this time within the religious respondents is related to the Canon Law, which regulates and governs a particular Christian organization such as the Catholic Church. Canon Law is specifically cited as the single reason for the anticipated failure of recomposition as a funeral method. The second catholic respondent, a Canon Law specialist, points out that convincing of authorities might be hard, despite public interest. Further, the respondent acknowledges the community's environmental and financial awareness of challenges surrounding traditional funeral methods. This suggests that authorities in Christian faiths interpret their holy texts in a traditional way, but opportunities to open a dialogue about novel processes exist, if these can accommodate aspects such as blessed grounds. The respondent specifically distinguishes between traditionalists and modern believers, attributing a greater likelihood of accepting recomposition to the latter. Considering the fairly large percentage of this denomination, cost might be a good argument to convince community members to interpret Canon Law more liberal to gain market share.

7.4.2 Representativeness

In absolute terms, the composition of responses (see 7.3) is not representative of the religious make up of Seattle (see Table 4). However, each group's response may be representative of their denomination across Seattle, based on the largely identical description of 'faith values' on the respective websites of the contacted survey participants' organisations.

Comparing Table 4 to Table 5, Seattle's religious make up is not representative for the whole of the US. This is particularly relevant since the only religious group to strongly reject recomposition is the Catholic denomination, which is underrepresented in Seattle compared to the whole country. In contrast, Atheist groups count less than a third of affiliations across the US compared to Seattle. The result of the survey can therefore be seen as a 'sugar-coated' version of the US population's general predispositions towards funerals and recomposition in particular.

Table 5: Religious groups in the US by tradition, family and denomination (Pew Research Center, 2017b)

Faith group	Religious denomination	Population share [%]
Christian	Protestant (aggregated)	46.6
	Catholic	20.8
	Other	3.3
Non-christian	Jewish	1.9
	Muslim	0.9
	Buddhist	0.7
	Hindu	0.7
	Other	0.3
Unaffiliated	Atheist	3.1
	Agnostic	4.0
	Other	16.4

Beyond the qualitative value of the survey, the question is whether the response rate allows any kind of meaningful interpretation. While Islam is not represented at all, there are two responses from Christian groups (most likely both are Catholic). The overall response rate is 7/49 or 14.3%, but with single responses from the Jewish, Hindu, Buddhist and Atheist communities, the survey is only an indicator and does not provide enough data to draw robust conclusions.

Despite the low response rate, the survey responses reflect official projections for the share of different deathcare methods (NFDA, 2015).

7.4.3 Survey and Interviews

As part of this project, a number of people with affiliations to deathcare in the Netherlands were informally interviewed. These were Thea Bruggraf (Tot Zover, Amsterdam), Rene Poll (Natuurbegraven Nederland) and Sabrina Franken (Yarden). Among the most significant themes were the rapid change of the funeral service industry in the context of technology as well as society, and dealing with the deceased as a business.

In chapter 1, history of deathcare highlights the emergence of cremation and most recently the innovation of resomation, cryomation and now recomposition. The Catholic Church's authority over funerals for centuries resonates in the survey in the sense that people are almost exclusively familiar with traditional burial and cremation only. Although this was confirmed by all interviewees, they all highlighted current developments of technologies and efforts to support these with scientific research in order to drive innovation in the industry. This also includes the expansion of services offered by funeral service providers. Here, the survey respondent seems to hold the contrasting opinion of funeral homes taking a much more passive role in the future.

Part of this development [in the Netherlands] is attributed to the fact that cemeteries are operated as for-profit private organisations and non-profit municipalities or foundations. Different funeral types incur different costs, which are especially driven by land-use in urban areas. In order to stay in business, these organizations are becoming increasingly competitive in the deathcare market. This is particularly challenging considering that religious rituals are still of importance despite the occasionally high associated costs (ie. grave and coffin in traditional burial). At the same time, new technologies are bidding for market share, while legislation may impose additional challenges, as is the case with flue-gas filters in crematoria. As Thea Burggraaf put it: "This is a business at the end of the day".

Understanding deathcare as an economic transaction may seem odd at first, especially since the church has traditionally taken over the role of funeral service provider in the past, burying the deceased in their own churchyard as part of a purely religious ritual. The influence of the church is still significant and can impact the lengthy legalization process of new methods (Kremer, 2017). However, since the Catholic Church accepted cremation in 1963, it may have opened the door for other methods too (Tekle, 2016). Legislation is one of the areas where Yarden actively pursues the evolution of the whole industry, beyond its own mission, according to Sabrina Franken. Although outdated, a brief overview of state bills and amendments (Bio Cremation, n.d.) highlights the necessity to collaborate with policy-makers beyond any individual technology of interest.

Beyond the technical, economic and legal factors, funerals are developing into a 'celebration of life' (Sabrina Franken) rather than a ritual of mourning over a dead body. The variety of quantitative and qualitative responses from the religious communities in the survey is testament to a funeral industry that has to cater to increasingly individualized and personalized ceremonies where faith may be interpreted in a much more liberal manner (Crabtree, 2010). Independently, this trend has been strongly confirmed by all interviewees and has led to Yarden's direct and transparent communication strategy of breaking taboos across all channels.

7.4.4 Literature background

The functions of cemeteries and funeral practices in social and spatial contexts are frequently addressed in literature. This subject is often confined to the cemeteries themselves rather than their situation within the cityscape, although she acknowledges their wider multi-functionality in terms of "green infrastructure (...), vessels of civic identity, telling diverse histories of the city and [representation of] intangible notions of the character of a given place" (McClymont, 2016). Conflicts can arise from different funeral practices and memorials, which may be a result of the trend of individualization identified by Crabtree (2010). However, activities within mourning spaces such as cemeteries can also lead to better intercultural understanding (Reimers, 1999), which can affect various elements of the cityscape and civic life (McClymont, 2016). A function of cemeteries as green infrastructure is defined by Kaplan's Attention-Restoration-Theory (Kaplan, 1995), where the visual exposure of humans to nature mitigates the exhaustive effects of focussing and concentration. This is especially relevant in urban settings (Milgram, 1970). In this sense, the spatial magnitude and quality of deathcare methods influence the well-being of their surrounding community and civic life at large.

Additionally, the extent to which funeral methods incorporate natural surroundings such as graveyard or remembrance gardens can significantly benefit biodiversity and ecosystem services in urban environments (Barrett & Barrett, 2001), and even preserve native vegetation and wildlife. This effect can be enhanced through coupling with non-invasive and non-disturbing practices (Wilson & Chiveralls, 2013).

Olson (2016) forms a compelling argument about the material and environmental challenges presented by the dead. Aside the importance of cultural and social context, the increasing volume of human corpses needs to be dealt with in an environmentally sensible and sustainable manner (Walter, 2005), which has recently initiated environmentally circular concepts of dealing with human remains (Rumble, 2017; Rumble, Troyer, Walter, & Woodthorpe, 2014). Further, Szmigin & Canning (2014) argue that innovation could also lead to funeral methods becoming producers of other commodities such as trees from natural burial grounds and waste-heat from cremation. This aspect of commercial benefit is particularly relevant in the US, where the funeral industry is almost entirely privatized and based on the economic relationship between business and customer for the purpose of displaying the dead as 'beautiful' (Walter, 2005). However, Washington Administrative Code 246-500-030 requires embalming if displaying the deceased for more than 24 hours or under special circumstances such as specific deceases (Washington State Legislature, n.d.), which in turn disqualifies recomposition or green burial as a funeral method.

In the US, mortality display and the final resting place both serve an audience whose residential mobility has historically been among the highest in the world (Clark & Withers, 2007). Casal, Aragones, & Moser (2010) found that "place attachment and place identity (...) play a crucial role in people's choice of a place for their remains". The same argument may result in deathcare methods being associated to certain mobility patterns, such as frequently moving families opting for cremation. This is particularly relevant, considering the largest age group of Seattle residents being young adults (Office of Planning & Community Development, 2016), who also show the highest rate of residential mobility in the country (United States Census Bureau, 2015). As a result, a large part of the population of Seattle might chose a deathcare method and location that resonates with a potentially low place attachment and/or high mobility behaviour. At the same time, the rapidly ageing population of Seattle may require more place identity-based deathcare methods.

Based on the aforementioned perspectives and factors, the Figure 20 was conceived as a means to compare the most frequent and significant functions of the deathcare methods considered in this study. Place of remembrance addresses the availability of a constant physical location of one's remains. Although ashes can be scattered, they are usually kept in urns at home or at a cemetery in the US (NFDA, 2015) and therefore partially become mobile.

Fostering nature/biodiversity in urban areas specifically can only take place if the final resting place involves some form of land-use that will not be otherwise occupied or transformed. Only methods which result in spatial allocation to the remains (specifically and non-specifically) such as burial and recomposition are valid options, while green burial always occurs in rural surroundings.
Useful recycling of human remains concerns the design of a method to intentionally utilize the energy or nutrients contained in the human body to feed biological or technical processes. Traditional burial does not satisfy this function because of frequent embalming and sealing of the grave.

Contribution to societal well-being is largely based on the effects of natural surroundings on the urban population (Kaplan, 1995). A distinction can be made in favor of recomposition, if the method advocates wilderness-like surroundings as opposed to the structured and developed nature of traditional cemeteries. Here, a visit to a green burial site left the authors of this study with a much more up-lifting sensation as opposed to emotions of sadness, depression and melancholy usually associated with cemeteries.

Deathcare as a sustainable business draws on non-profit models such as the UDP itself as well as Yarden, resource-sensible practices such as low land-use and social integrity through dignity, inclusion and contributions to the community. These factors are particularly evident in the case of the UDP, where material outputs are envisioned to enrich local habitats.

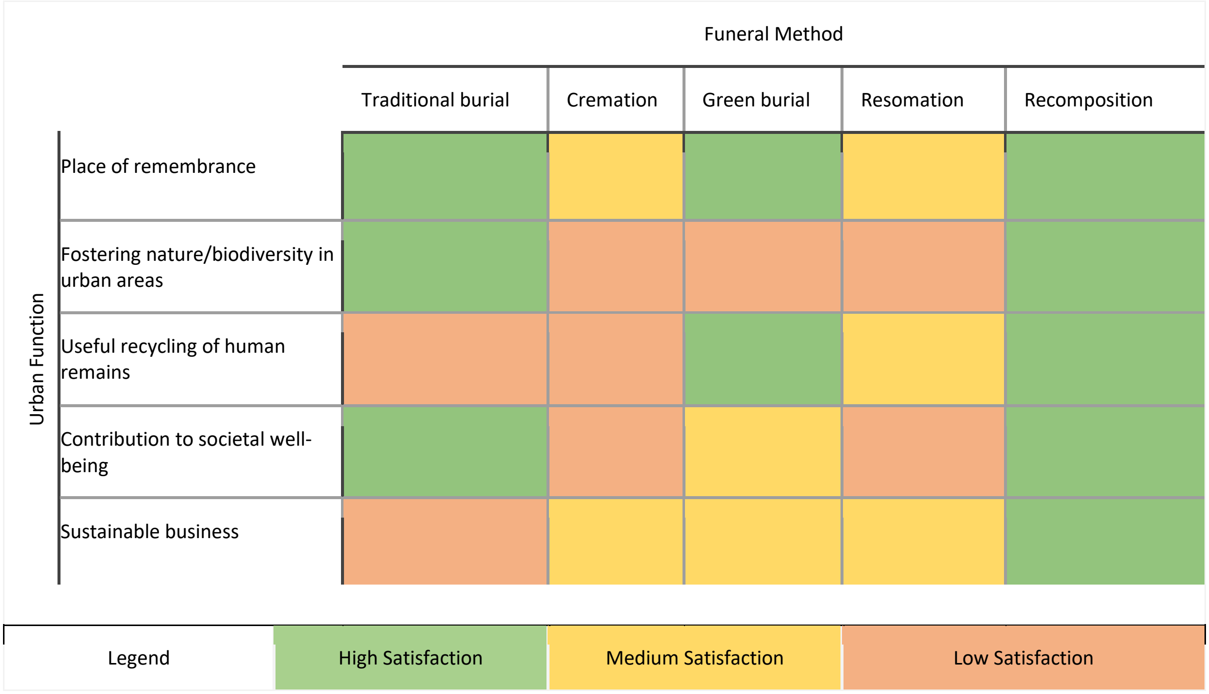


Figure 20: Urban function satisfaction matrix

7.4.5 Information value for the UDP

The survey, literature review and interviews have revealed two messages, which may be particularly useful for the UDP in developing their strategy.

First, among the surveyed religious groups, the Catholic community seems to be most reluctant to adopt recomposition due to stipulations defined in the Canon Law and the uncertainty about whether blessed grounds will be possible/available. However, the respondents have signalled the possibility for recomposition to be accepted by the less traditional followers, as they increasingly consider environmental impacts and costs of funerals to be important factors. Addressing the Christian concerns about any novel funeral type is essential, since half of Seattle's population affiliates with this faith group. Further, legislators in other states have shut down approval of resomation after the Church rejected the method. Nevertheless, Seattle is among the best locations in the US to launch a new deathcare method because of the large segment of the population which is not affiliated with any religion. Although the environmental and financial arguments weigh in the most with these community groups, particularly cost is becoming a major factor for everyone. In urban environments, land-use of graves and crypts adds significant costs. Although the UDP's vision includes land occupation around the recomposition facility, ownership and use of the grounds might affect the cost to the client. In case of an arrangement with the municipality, where the surroundings are equal to a city park and maintained as such, the cost to the UDP would decrease. Further, if the output from the recomposition process attains the legal status of a good, this would open a second revenue stream for the facility, which could be secured through the direct application on the adjacent city park. However, there is no indication that lower costs compared to other methods will increase the likelihood of adoption of recomposition.

Second, the survey indicates a communication gap between the service providers and their clients. The sometimes significant discrepancy of each other's perception represents a notable opportunity for the UDP, which can position itself at the head of the evolution of the whole industry. Yarden in the Netherlands – also a non-profit organization– operates in a different environment and offers all types of deathcare methods, but has achieved universal recognition and industry leadership status because of its sober, direct and transparent communication with all stakeholders through public channels. Although this strategy is effective in the Netherlands, the survey does not address how it could be applied in the US. Further, the surveyed representatives of faith groups only interpret how citizens translate socio-cultural norms and environmental and economic constraints into action when choosing a funeral method for themselves or a family member. The data is therefore effectively secondary information and should be consumed critically.

Finally, this part of the study intended to assess the level of social acceptance of recomposition among sub-communities in the Seattle Metropolitan area, based on a combination of methods. The survey responses from six representatives of five faith groups and one funeral director indicate that death and deathcare are no taboo topics and generally attest their respective community members an openness towards new methods such as recomposition. Some responses point towards an ongoing and profound change in deathcare, where spiritual and financial considerations are likely to be equal factors for the selection of a funeral type, which would increase the likelihood of people's consideration of recomposition. The recomposition process and its output especially appeal to non-religious people more than any other method, because of the combination of ethical treatment of the corpse and environmentally sensible disposal. In Seattle, the adoption of recomposition as a deathcare method is therefore expected to be mostly dependent on other aspects such as successful legalization, technical optimization and economic feasibility, while a large portion of its citizens seem receptive to the concept already.

7.5 Recommendations for further research

The intention of this study was to shed some light on the perception of funerals and in particular the novel method of recomposition among religious groups and industry in the Seattle Metropolitan area. The survey achieved that goal with the help of supplementary information from literature and interviews. However, the low response rate of target group representatives and its context of faith (for the religious groups) do not accurately reflect the whole population of Greater Seattle. Different strategies of population segmentation, such as political affiliation or age group, may complement this study or better reflect the local communities' opinions. The context of faith was chosen in order to access information easily through representatives and within a short schedule. Additional demographic surveys can address citizens directly through a variety of channels such as direct mail, telephone, in public or web-based. As a result, more non-mediated responses can provide a better picture of people's opinions. Further research should also address directly, how people go about deciding on a funeral method as well as when they make these decisions. This aspect is meant to highlight how the conflicts between spiritual and worldly considerations are resolved and where the UDP may be able to build leverage. Other than through direct interaction with the population, this leverage can also be based on communication with other stakeholders such as insurers and zoning authorities, who have been excluded from this study. This may particularly aid the legalization and implementation process of recomposition in Seattle.

Finally, this study focused on the perception of recomposition rather than novel methods in general. The development of resomation and cryomation may provide valuable insight, especially if any socio-cultural research is available for these cases. In the case of the Infinity Burial Suit by Jae Rhim Lee, an emphasis was put on the environmental aspect of human mortality, an aspect which is also significant for the UDP. A detailed investigation of the evolution of the Infinity Burial Suit project could highlight important factors, which may help adjust the UDP's mission and vision in order to achieve success.

Chapter 8 Economic analysis

8.1 Introduction

An important part of deathcare is, besides of course the emotional aspect, the financial costs. In case one wants to arrange a proper farewell for someone close to them, this inevitably comes at a price. As Bern-Klug et al. explain the person that is responsible for the choices involved in deathcare (such as choosing between different funeral technologies) is overwhelmed by grief, which severely affects one's decision (Bern-Klug et al., 1999). Furthermore, in a survey they performed amongst survivors half of the respondents indicated to be unaware of the financial costs involved in deathcare (Bern-Klug et al., 1999). This stresses the need for more clarity on costs involved in different funeral technologies. It also raises the question whether the financial implications of deathcare influence the choice for a certain deathcare technology.

The consumer costs of the different funeral technologies currently do not include the environmental impact of the different funeral technologies. Especially from the perspective of sustainability and 'pay what you pollute', it is most certainly important to take a look at these costs. From a sustainability perspective, these costs should be added to the consumer price of each funeral technology so that their respective environmental impacts are compensated. However, taking care of the body of a beloved one is already very expensive and has a huge impact on people's savings and spendable money (Corden et al., 2013). Therefore, an argument can be made to exclude the costs of the environmental impact since it already has a large economic impact on consumers. A fair pricing model could tackle this argument. This entails that people with a higher income will compensate for the environmental impact of those with a lower income. By setting out such a model, the environmental impact of a funeral technology could be included in the prices, which leads to compensation for the environmental damage.

Since a funeral is the third most expensive consumer purchase of a lifetime, one can imagine that not everyone can afford to pay for a funeral (Bern-Klug et al., 1999). In a survey that specifically researched the effect on the level and sources of income, held amongst 44 relatives of deceased people in the UK, it was found that income from paid work of under pension aged people declined by half after the decease of a loved one, which accounts for ninety percent of the total loss in household income of this group (Corden et al., 2013). Although there are state bereavements benefits, there's low awareness about this and the eligibility standards are often not well understood (Corden et al., 2013). Add the costs of a funeral to this and chances for a family to keep its finances in check further decrease. It is therefore important to examine in what way we can make funeral arrangements more affordable to people with lower incomes and make them more aware about these costs to prevent financial problems in times that people are already in distress due to the grieving over a loved one.

When aiming to include a new funeral technology to the list of available technologies, as the Urban Death Project aims to do ("Urban Death Project," 2017), it is relevant to review the factors mentioned above. For the viability of recomposition, it is important to see what the costs of recomposition would be. Both from an organizational and a consumer perspective. The costs need to be balanced with demand in order for recomposition to be viable. However, the demand for this new funeral technology is still unclear as is mentioned in the social-cultural analysis. A way to review this is to see what the impact of the financial burden of deathcare is on the choice of funeral technology according to citizens in Seattle. By comparing the consumer price of recomposition to those of other funeral technologies, a clearer view on the economic viability of recomposition can be established. A final important aspect is assessing the viability of the suggested fair-pricing model of UDP, as this model is a unique selling point of UDP in the funeral technology market.

While reviewing all this information, the question arose *whether the economic context serves as a driver or barrier for the development of recomposition as a new funeral technology*. In order to answer this question several topics are highlighted. This economic analysis aims to outline the awareness of the financial costs of deathcare by means of a survey. Furthermore, it aims to outline the costs of different funeral technologies in the US in order to clarify the differences. Finally, the idea of fair environmental compensation by means of shadow costs is researched as a means to involve the environmental costs in the different funeral technologies and show the 'true' costs. A discussion on the relevance of this research to the UDP will be included in the end. The next section will elaborate on the methods used to research these three topics.

8.2 Methods

The first part of this economic analysis elaborates on what way and to what extent the choice for a funeral technology is influenced by its financial implications. This study aims to see what funeral directors notice in the behavior of the people they encounter in their work and in what way they think costs affect their decisions. Furthermore, a survey amongst religious representatives was held in which was asked to what extent financial implications play a role in the decision for a funeral technology. As the surveys that were held were not primarily focused on the economic aspects of deathcare, limited information is available to make conclusions. Therefore, the conclusions and implications of this survey are by no means a good representation of the real world. However, it can serve as an indicator of where to search for more answers or where improvements can be made.

In order to clarify the costs involved in the different funeral technologies this research will provide an estimation of the costs by means of a back-of-the-envelope calculation. It will focus, where possible, on prices in Seattle or Washington State in order to enable a viable comparison. Adding to that, the prices of as many different funeral homes and sources will be taken into account and an average will be composed from that. Most important sources of finding data will therefore be funeral homes and research into deathcare costs. The additional costs of a ceremony, flowers and the like will not be involved in this study since this differentiates between funerals and is not necessarily connected to the funeral technology that is chosen. All costs mentioned will be in USD.

The final part of this research elaborates on the costs of the environmental impact. To calculate this, shadow costs are used. These are the costs related to environmental impact. Shadow costs can be calculated by means of the abatement costs or the damage costs. For this study the damage costs will be used. This means the shadow costs are based on what people are willing to pay to prevent damage to the environment (de Bruyn et al., 2010). The shadow costs of the different funeral technologies are based on the most recent study available (Keijzer, 2016) and in order to connect these costs to the different funeral technologies the outcomes of the comparative LCA study are used that is elaborated upon in more detail later in this report. The valuation of the shadow costs in euros is converted into USD in order for it to be coherent with the rest of this report. According to the European Central Bank, the exchange rate of 1 euro is 1.12 USD on May 26, 2017 (European Central Bank, 2017). This rate will be used to convert the shadow costs in euros to USD. It is important for the reader to keep in mind that the numbers on environmental impact categories are dependent on the assumptions made and it is therefore strongly advised to read the comparative LCA section of this report. Most important thing to realize when interpreting and using the shadow costs is that these are not set in stone and can vary when different choices in LCA modelling are made. This research will therefore merely provide an indication of the shadow costs and suggest a way of using these costs in integrating the environmental costs in one of the funeral technologies. A fair pricing model based on income distribution in Seattle shows a way in which fair-pricing can be realized. This is applied to the case of recomposition.

8.3 Results

8.3.1 Influence of economic costs on choice of funeral technology

According to Bern-Klug et al. (1999) funeral arrangements are the third most expensive consumer purchase of a lifetime, just after the costs of a house and a car. This indicates that the choice of a funeral technology (and the expenses that come with it) can have a high impact on a person's life. Corden et al. (2013) found in the outcomes of their survey that the spendable income of a household declines severely after a person's death. This stresses this message even more. However, none of the researchers have studied whether the costs tied to a funeral influences the choice of the applied funeral technology. Therefore, by means of a survey, this reports aims to find this out.

Unfortunately, there were only seven responses to the survey conducted for this study, which was held amongst religious representatives, which makes it hard to make any solid conclusions. Nevertheless, this can serve to provide an indication. According to the survey held amongst religious representatives, financial implications only play a mediocre part in influencing the choice for a funeral technology. Societal expectations and practicalities seem to play a far more important role according to their survey submissions. The answers from the funeral director to our survey indicated that financial implications are highly significant in terms of choosing a funeral technology. This answer seems to contradict the notions of the religious representatives. Further research is therefore needed to analyze to what extent the financial implications truly affect the choice of a funeral technology. However, giving the results from the research from Corden et al. (2013) and Bern-Klug et al. (1999), people often have no clue what arranging a funeral costs and there is an imbalance between funeral director and customers in terms of knowledge about these costs. The grief a customer is experiencing can result in people underestimating the importance of the financial aspects when choosing a funeral technology, since they have no knowledge of the affiliated costs. This should therefore be taken into account in further studies. It could be that more openness about the costs would increase the influence of the economic costs on the choice of a funeral technology. Also worth researching is to what extent the intrinsic value of the manner of saying goodbye to someone (cremation, burial or in another way) outweighs the financial burden to people. Concludingly, the influence of economic costs on the choice of a funeral technology seems to be smaller than societal expectations and practicalities. However, more research is required to provide a definitive answer to this question.

8.3.2 Overview of costs per funeral technology

According to a survey of funeral home prices in Washington State performed by the People's Memorial Association, differences in cremation prices vary up to 700 percent. The prices for burial vary up to 400 percent (People's Memorial Association, 2016). This shows it's hard to set an overall standard price for different funeral technologies. In order to understand the differences in cost between different funeral technologies, certain assumptions have to be made.

Immediate burial and direct cremation

This research will look at costs of immediate burial or direct cremation since these costs do not include a ceremony (Columbia Funeral Home, 2014). Direct cremation and immediate burial include costs for storage, refrigeration, transportation to the site and the cremation process. Furthermore, it covers the basic services of the funeral director and staff in terms of filling necessary permits and aiding transportation. These prices include taxes, county fees and death certificates (Howden-Kennedy Funeral Home, 2014). The table includes the average price of the known costs in Seattle. These prices are known for Columbia Funeral Home and Howden Kennedy Funeral Home.

Interesting to see is that immediate standard burial is a lot more expensive than direct cremation whilst the direct cremation also includes the cremation process. This can be explained by looking at the transportation. The transportation of the body to the grave site, which is not included in direct cremation, is one of the largest expenses concerning deathcare (Everplans, 2017). This can also be found in the descriptions provided by the Howden Kennedy funeral home; the only difference between the two options is the transport of the body to the grave for immediate burial and the cremation process for direct cremation (Howden-Kennedy Funeral Home, 2014).

The price for casketed burial (placement of remains of burial) is composed by taking the average of the prices of different cemeteries in Seattle found in the cemetery price survey of 2011 (Personal Alternative, 2011). For the placement of the remains of cremation it is assumed that the urn is buried. This value is calculated by taking the average of the known prices.

Blackwell (Blackwell, 2010) and Eastwood (Eastwood, 2014) provided an indication of 2,000 USD for an average casket. This is in line with the reimbursement rate of the Department of Veteran Affairs. The reimbursement rate is meant for veterans that died with no next of kin or where there are insufficient financial resources. The reimbursement they provide is 2,069 dollars for a casket and 163 dollars for an urn in 2017 (Martin, 2016). For this research we will take those numbers as standard prices that are paid for caskets and urns.

Resomation

Since research regarding the process of resomation is scarce, this section of the economic calculation mainly relies on the information provided by the Anderson-McQueen funeral home. The Anderson-McQueen funeral home was the first in the US to adopt resomation as a funeral technology (Pappas, 2011). According to general price list biocremation, or resomation, costs around 695 dollars. To put this in perspective; the costs for traditional cremation are 550 dollars at Anderson-McQueen funeral home (Anderson-McQueen Funeral Home, 2016). The same difference in price is stipulated when discussing the costs for direct cremation. They simply state, for the same services but then using the biocremation technology instead of the traditional cremation technology, add 145 dollars (Anderson-McQueen Funeral Home, 2016).

Since there are few other sources the actual costs of the process can be derived from, for now it is assumed that the mere technology of resomation costs around 145 dollars more than the traditional cremation technology. Since costs for direct cremation (including the same services as stipulated in the former calculations) are way higher (3,295 USD compared to the 1,500 USD found during the research) the final costs for direct resomation are calculated by adding 145 dollars to the 1,500 dollars costs of direct (traditional) cremation instead of adopting Anderson-McQueen's numbers. Since all other involved services, like the urn and placement of the urn, are the same the costs involved in cremation are adopted for resomation. This assumption is validated because the outcome of resomation (a powder) is handled similarly as the ashes from traditional cremation.

Green burial

In order to determine the costs of green burial it is important to stress the differences between green and traditional burial. The main differences are that green burial requires bodies to not be embalmed. Furthermore, caskets (if desired) and shrouds are made from biodegradable material and there are no concrete vaults or grave liners. Additionally, if one desires a green burial, this should take place at a cemetery that the Green Burial Council has recognized as a green burial site (White Eagle Memorial Preserve, n.d.).

As the storage, transportation to site and refrigeration do not deviate from standard burial the same amount is assumed for natural burial. A biodegradable casket is sold for 299 USD at the Alternatives Funeral & Cremation Services (Alternatives Funeral & Cremation Services, 2017). This is substantially cheaper than the average costs for a casket in standard burial. In case a relative decides to choose for a shroud, costs are also around 300 USD (Pritchett, 2011). Since embalming is not allowed in green burial, these costs are left out in this funeral technology. The White Eagle Memorial Preserve is one of the few natural burial sites in Washington State which is transparent about the costs involved in the placement of the remains in case of natural burial. According to their website the baseline costs for a plot is 2,500 USD. Adding to this comes a 600 dollar fee for opening up the plot, placing the remains and closing it afterwards (White Eagle Memorial Preserve, n.d.). This means that the total costs involved in the placement of the remains are 3,100 dollars.

Recomposition

Since recomposition is currently not a practiced form of deathcare the costs for this are hard to define. The costs will therefore be composed from calculations, assumptions and information from other deathcare options.

Looking at the costs for immediate burial (1,945 USD) and direct cremation (1,500 USD), the difference between the two costs can be perceived as the transportation costs to the grave site. Since this can be disregarded for recomposition we can look at the costs for direct cremation. This still includes the fee for the cremation process. According to the Columbia Funeral Home (2014), the price for the cremation process is 375 dollars. Since this is the only source to be found specifying the costs for the actual cremation process, the assumption is made that this is the final fee. Therefore, the costs for recomposition, without the recomposition process, will come down to about 1,125 USD.

The costs for the recomposition process are still unknown, which means rough estimations of what is required for this process will make up these costs. What exactly is required for this process is described by the Urban Death Project, which is currently researching options to offer recomposition as a form of deathcare. Numbers used to make up these estimations are taken from the LCA Inventory Data composed by dr. Hottle.

Since the costs for building the crematory or the funeral home which holds the body refrigerated weren't taken into account, this will not be done for recomposition either. The costs for the recomposition process are dependent on the amount of alfalfa and woodchips needed per body and the electricity costs for stage 1 and 2 of the process. The amounts needed per body can be found in appendix B.1.1. The market value of alfalfa is determined by taking the current prices. It is assumed that the alfalfa for recomposition is bought in great quantities which could lead to an overall price reduction. According to the Hay and Forage Grower, a magazine on agricultural products, the price of alfalfa was 90 USD per ton in Washington State, as per 9 May 2017 (Hay and Forage Grower, 2017). For the wood chips, no accessible reports or records on current prices could be found. The price for this is taken from a wood chip producer in Washington State and is set at 140 USD per ton (NorLan Log & Lumber Company, 2017). The electricity used for the elevator and the two stages of recomposition is currently priced at 0.0413 dollar per kwh (Washington State Department of Commerce, 2017).

The costs for a biodegradable shroud is assumed to be around 300 USD, which is the same as for natural burial (Pritchett, 2011). The placement of the remains in recomposition is in a park. In line with other research performed for this report, it is assumed that the park is 1/4th of a soccer field (100 *64 meters) minus 70 square meters for the building. The total area of land that is required is therefore 1530 square meters. The average price per square meter of land in the city center of Seattle (Capitol Hill) was 528 USD in June 2016 (Trimbath, 2016). The costs for the park would only have to be paid once, namely at the beginning. That means that a total of 807,840 USD needs to be divided over all the people that are recomposed. Since there is no definite time span for recomposition and a facility can, in theory be there for a long time, a time span of 83 years is assumed. This is in line with the research on land use and the LCA for this report. Furthermore, corresponding to the estimation that Troy Hottle provided, it is assumed that each week one person will be recomposed. Since the calculation for the processing costs for recomposition is based on the price for cremation and burial, this includes wages for caretakers. However, in the placement of the remains the wages for caretakers is not included. Therefore it is assumed that it takes one person every day to take care of the remains. According to Working Washington, a workers movement active in the state of Washington, the minimum wage is 15 USD per hour (Working Washington, 2014). This means that the minimum yearly salary is around 30,000 USD. Adding up all these costs, a total of 764 USD needs to be paid for the placement of remains for recomposition.

Comparison of the 5 alternatives

Table 6 below shows an overview of the consumer costs for all different funeral technologies.

Table 6: Overview of costs per funeral technology

Funeral technology	Immediate standard burial	Direct cremation	Resomation	Immediate green burial	Recomposition
Processing costs (Storage, refrigeration, transportation to grave site and cremation/resomation/recomposition process)	$ 1,945	$ 1,500	$ 1,645	$ 1,945	$ 1,402
Casket/urn	$ 2,069	$ 163	$ 163	$ 300	$ 300
Placement of remains	$ 6,040	$ 1,677	$ 1,677	$ 3,100	$ 764
Embalming	$ 595	$ 595	$ 595	-	-
Total costs	**$ 10,054**	**$ 3,340**	**$ 3,485**	**$ 5,345**	**$ 2,466**

Recomposition seems the cheapest funeral technology out of the five. However, this is only when the ashes from cremation and resomation are buried. Since the placement of those remains take up a substantial part of the total costs, both would be cheaper to the consumer than recomposition in case the ashes are shattered or taken home and placed there. Since this is more common in Seattle than to bury the ashes, according to mr. Hottle, actual prices would be lower. Another interesting remark to make is that following the Washington State law, it is illegal to have a viewing of the body without it being embalmed. This means that it is likely that all funeral technologies, except for green burial and recomposition, where embalming is not allowed, will have a higher costs outcome. The 600 dollar of embalming costs should be added to those prices in some cases. Even if this is added, resomation and cremation are still cheaper than recomposition.

8.3.3 Fair environmental compensation

The previous section described and compared the costs of the different funeral technologies to the consumer, but these costs do not include the environmental impacts. This section will therefore include an overview of the overall costs of the environmental impact per funeral technology. Furthermore, using the calculated shadow cost for recomposition, a fair pricing model is composed as a means to lower economic pressure on customers with a lower income.

Appendix B.2.2 shows the calculations for the conversion of the shadow costs. Some of the impact categories have an amount of money connected to their impact. That is because the shadow costs of these impacts are zero, because these impact categories could not be valued in terms of money. This affects the outcome of the overall shadow prices. For example, traditional burial has an impact of 19.25 kg Fe equivalent whilst the other funeral technologies have negative or almost no impact. This means that if metal depletion could be valued in terms of money the shadow costs for traditional burial would be substantially higher. Another important thing to highlight is the water depletion impact category. The shadow prices were obtained from Keijzer (2016) as can be seen in appendix B.2.1. Her research states that the m3 water depletion to shadow cost ratio is 1. Since the outcomes increased our shadow costs by a factor of 10 or more, as appendix B.2.2 depicts, this affected the outcomes of the shadow prices severely. An error in the characterization factor for water depletion is most likely the source of this incredible high outcome and therefore this impact category is left out in the shadow costs calculations.

The impact category which influences traditional burial the most is urban land occupation. This impact category is responsible for more than 80 percent of the total shadow costs of burial. The same thing can be found when looking at agricultural land occupation for green burial. More than 95 percent of the total shadow costs comes from this impact category. The other funeral technologies show quite low costs for both these factors. The most influencing factor for recomposition is particulate matter formation. This makes up more than 50 percent of the total shadow costs for recomposition. Same goes for resomation. Reducing this environmental impact will ensure severe savings in terms of shadow costs for both funeral technologies.

The funeral technology that comes out best, or which is the cheapest in terms of shadow costs is cremation, as can be seen in Table 7.

Table 7: Shadow costs for the different funeral technologies

Funeral technology	Burial	Cremation	Resomation	Green burial	Recomposition
Total shadow cost per funeral technology	€ 205,.6	€ 21.46	€ 18.31	€ 324.59	€ 33.39
Euro to USD conversion factor	1.12	1.12	1.12	1.12	1.12
Total costs in USD	**$229.90**	**$24.04**	**$20.51**	**$363.54**	**$37.40**

What would be interesting from an environmental perspective is to include the aforementioned shadow costs in the price for a funeral technology. To provide an example of a manner of doing so, the shadow costs of recomposition will be included in the price. The question is whether it's fair to let everybody pay this same additional price. Therefore, this is combined with the vision of UDP, the only organization currently looking into the actual implementation of recomposition, to implement a fair-pricing model. This means that people with higher income pay more than people with lower income to balance out the inequalities.

In Seattle, the median income per household was 80,395 USD in 2015 (City-Data.com, 2015). Looking at the division of income classes in appendix B.3, it can be seen that the average Seattle citizen falls in the upper middle income class (American Community Survey, 2017). An overview of the division of income amongst the Seattle households is also shown Appendix B.3. For the calculation of the fair price, the fact that more than 50 percent of the households has an income of above 75,000 USD is taken into account. Therefore, the upper middle class and high income households will take up the costs that the other classes don't need to pay for. For this model, it is decided that the low income households don't pay the shadow costs, the lower income class pays 25 percent and the middle class 75 percent of the shadow costs. This means that the upper middle class takes 190 percent and the high income household 210 percent of the shadow costs to account for the costs of the other classes aside their own costs. The resulting 'fair price' for each income category is shown in Table 8.

Table 8: Fair price per income category

	Low income	Lower middle-class income	Middle class income	Upper middle-class income	High income
General costs	$2,466.00	$2,466.00	$2,466.00	$2,466.00	$2,466.00
Shadow costs	0	$9.35	$28.05	$71.06	$78.54
Fair price	**$2,466.00**	**$2,475.35**	**$2,494.05**	**$2,537.06**	**$2,544.54**

Since the people choosing for recomposition as a method of deathcare might not be evenly distributed amongst the five classes this might not be a correct example of a fair price model, but it shows an indication of how to compose one. For example, in case more people with a low income would choose for recomposition, people with a high income would have to pay a larger amount of the shadow costs. This should therefore be researched further before taking over this model.

8.4 Conclusion and discussion

The influence of economic costs on the choice of a funeral technology is something that definitely requires more research. However, as Corden et al. (2013) and Bern-Klug et al. (1999) already experienced, death and deathcare is a difficult topic to talk about which makes researching this topic quite difficult.

The literature study shows that there is currently little to no knowledge of the costs involved in deathcare amongst consumers. An overview of the costs per funeral technology can help to clarify and allow customers to make a well grounded choice. It can be concluded from this cost overview that recomposition is not necessarily the cheapest technology, however, it is substantially cheaper than any other form of burial. It falls within the same price category as cremation and resomation, whilst providing the same service from another perspective. Important to understand is that cremation (or resomation) technologies and burial (traditional, green, or recomposition) technologies all provide the same service, but are likely to be perceived differently by the public due to religious and/or personal preferences. Therefore, recomposition can be viewed as the cheapest burial alternative. Also important to note is that the processing costs are based on the costs for burial and cremation and therefore includes profit, which UDP will not include in their prices as they are a non-profit organization. This means actual prices might be lower in this aspect. Also noteworthy is that the placement of remains for recomposition are based on the estimations made by Troy Hottle, additional calculations and assumptions in terms of numbers of deaths and land prices in Seattle. Changes in these assumptions can severely affect the price. Adding to that, changing the time span to correspond with the time span for a loan, which is also often done, can make the price per deceased a lot higher for recomposition.

Involving shadow costs in the price for a funeral technology is not done currently in Washington State and therefore the provided model is purely hypothetical. Important to note here is that the shadow costs used are based on the perspective of EU citizens, not American citizens. This means that the actual shadow costs for Seattle may differ from the ones used here. The shadow costs show that burial would be affected most in terms of rise of the price. Since burial is already a very expensive funeral technology this makes the choice for this technology from an economic perspective even less attractive. Recomposition doesn't score very well in terms of shadow costs; the shadow costs are more than double the costs of the other three technologies. However, this is strongly affected by the fact that all environmental impacts are allocated to recomposition whilst partial reallocation might be possible if the compost that comes out is perceived as a fertilizer or other good. Since this is legally not yet possible, the outcome of the study is taken to see in what way the lower income households can be spared in terms of financial burden. If the provided model is applied, the burden on the lower incomes would be around 3 percent less. This does not really lessen the burden on the lower incomes. It seems that not only the shadow costs should be allocated by income but also a part of the general costs in order to substantially relieve the financial burden on the customers with a lower income.

By combining the three parts of this economic analysis, this study has achieved the goal to provide an indication for the actual costs per funeral technology, but has failed to show what the impact of the financial burden is on the choice of a funeral technology. Furthermore, involving shadow costs in the price of a funeral technology could be a way in which the environmental impact of the technology is accounted for. However, using these costs to set up a fair pricing model shows not to be the answer to relieve the lower incomes of the financial burden. Due to a limitation in terms of available literature and the aforementioned restraints, a conclusive answer to the question *"does the economic context serve as a driver or barrier for the development of recomposition"* can therefore not be given.

The costs for recomposition appear to belong to the lower category of the available funeral technologies in Seattle, which could be a driver for consumers to choose for recomposition. However, since this research was unable to clarify to what extent the financial burden affects the choice of a funeral technology, it remains uncertain whether this statement is actually true. The fact that a lot of consumers are unaware of the costs of the different funeral technologies questions the influence of consumer price on the demand for recomposition even further. However, UDP (together with other organizations) could provide more clarity in the costs involved in both recomposition and other funeral technologies, so that consumers can make an informed decision and prevent high debts due to unexpected costs. As the UDP aims to include fair-pricing in order to lessen financial burden on lower income households, a redivision of the shadow costs shows to be insufficient. As the shadow costs are only a small percentage of the total consumer costs of recomposition, this makes hardly any difference in terms of reducing the burden. A model including both a redivision of shadow costs and of a part of the consumer cost is therefore advised. Redivision of a part of the consumer costs should be based on research that shows how many people of the different income classes would choose for recomposition in order to reach a balance and cover all costs.

8.5 Recommendations for further research

In order to fill the gaps highlighted in this research, more time should be spent by researching the three aspects of this analysis. Due to time pressure this was not realistically achievable in this study. A more complete survey with more focus on the economic aspect of deathcare and a bigger audience should be performed. A survey held within the US should show the damage costs US citizens subscribe to the different impact categories which makes the shadow cost study a better relation to the US case study. Since the shadow costs show to not be an answer to relieve the financial burden of deathcare on the lower incomes, more research on how to reduce the general costs for this group should be performed.

Chapter 9 Land use modelling

9.1 Introduction

Pyramids in ancient Egypt, columbariums in ancient Rome and natural burial sites of the Celts - deathcare practices have throughout human history required a lot of land to be realized. In this part of the study, the land use impact of the five different deathcare methods are analyzed in a dynamic system over the course of 83 years. The purpose of this land use model is to forecast land use developments in Seattle in a number of scenarios. In order to realize a mix of deathcare methods with the least required land use and to accurately compare the different options. The aim is to measure the quantity of land use change rather than the explicit spatial implications. The research question this section seeks to answer is: *What can land use models tell us about differences in potential land use impacts of the five technologies under study?*

9.2 Methods

The land use study is conducted in a form of dynamic system modeling by using the software Vensim Pro. This software was chosen because it is available for TU Delft students and fulfilled the modelling requirements. Before the actual modeling, a literature research was conducted in order to gather information on the different variables affecting the dynamics of the land use of the technologies under study. This information is gathered from governmental and private company websites, newspapers as well as scientific papers. The five deathcare methods included in the model are the following: (1) burial, (2) cremation, (3) resomation, (4) green burial and (5) recomposition.

The system under investigation is the deathcare system of Seattle. Only the dynamics of population are considered; no political, social or economic dimensions are affecting the model. The model includes two parts: firstly, modeling the land use requirements of the five technologies exclusively (100% advocation). Secondly, modelling the land use requirements in three different scenarios which include a mix of different technologies. These scenarios are presented in more detail in the next section.

The model constructed in Vensim Pro is presented in Figure 21. Furthermore, all the calculations performed in the model can be found from the appendix on page.

9.3 Foundation of the research

In the US, burial was considered as the primary form of deathcare for decades and only since the 70's has cremation become a mainstream practice. Nowadays, 48,6% of the deceased in the US are cremated (CANA, 2015). Washington State, which has with 75,5% the highest percentages of cremation of all states (CANA, 2015). The overall trend is a decrease of burial practices and increase of cremation as well as other alternative practices such as green burial. In this chapter, all the five burial methods under study for land use are assessed based on literature. This introduces the main variables of the model and clarifies the assumptions made.

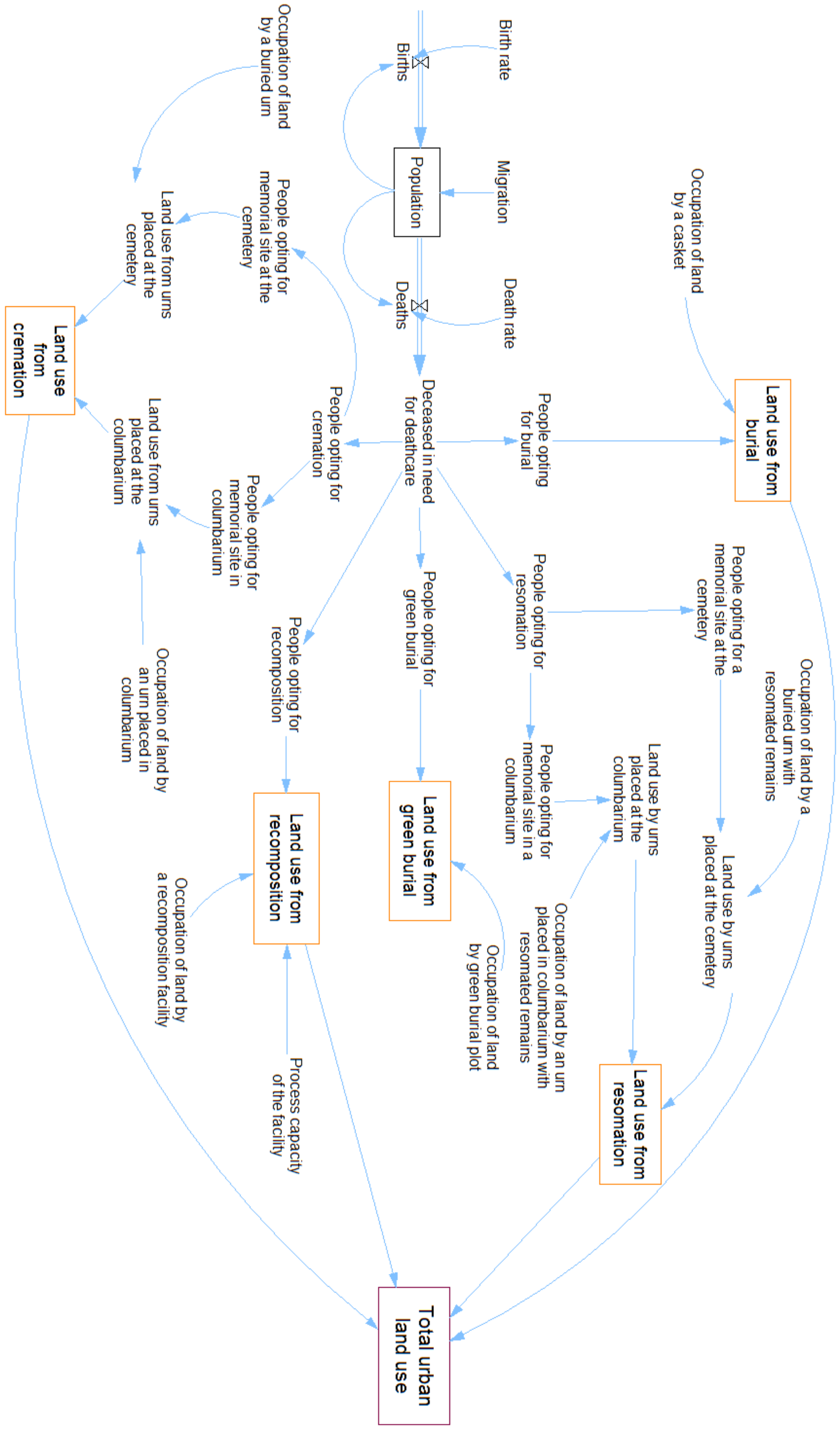


Figure 21: Vensim Pro model

Population

The population dynamics of the model take the natural population growth as well as net migration into account. The average birth rate in the US is 12.4 per 1,000 and the death rate is 8.2 (The World Bank, 2017). As Figure 22 shows, the 12.4 is the lowest birth rate in the US for the past 55 years.

The people of Seattle account for 23% of the population of the whole Seattle metropolitan area, which has in total approximately 2,895,300 inhabitants (Forbes, 2017). The metropolitan area of Seattle experiences a net migration growth of 7,300 people/year (Forbes, 2017). Based on this, under the assumption that 23% of the net migration takes place in Seattle, the city of Seattle gains 1,679 new residents yearly.

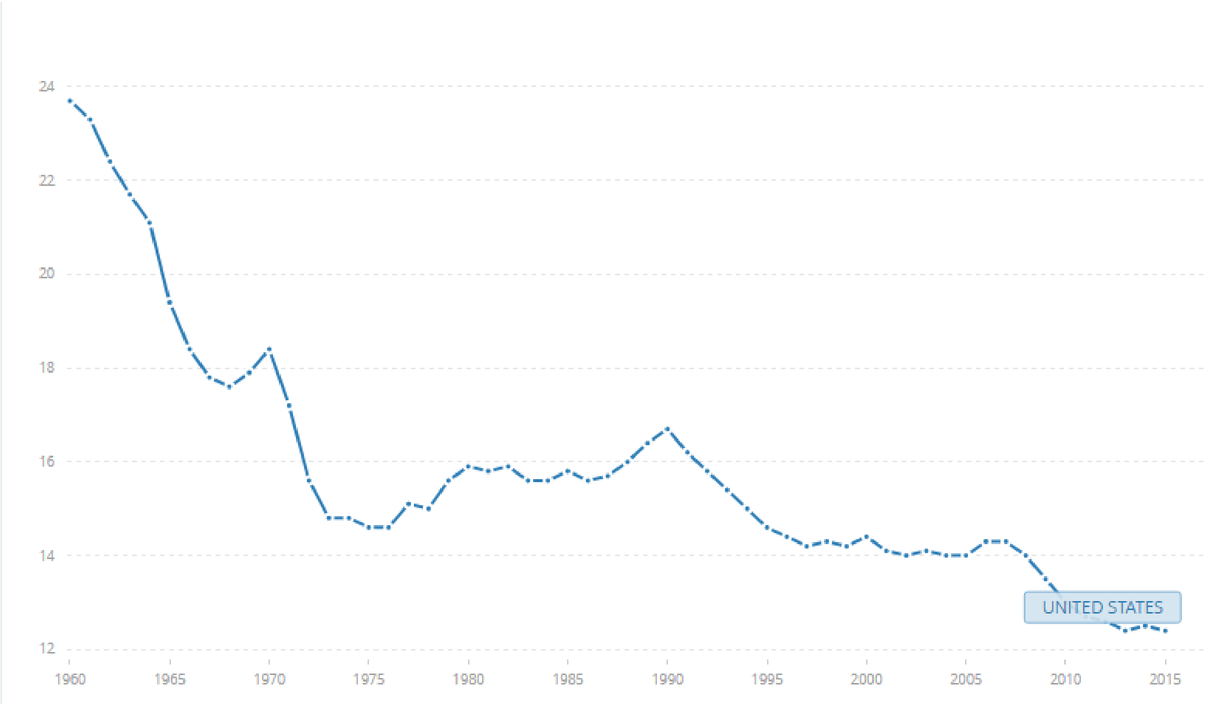


Figure 22: Birth rate in the US over the past 55 years (The World Bank, 2017)

Burial

In the US, a grave is purchased for eternity. In a 1978 US Supreme Court decision, one cannot disturb a body without a valid reason (Zars, 2011). This includes operating cemeteries as well as abandoned cemeteries. This practice of "final resting place" within the US naturally enforces the crowding of cemeteries as no recycling of graves is possible according to the law. Due to these laws, it is assumed in the model that each new body will have to be buried on a new piece of land. It must also be stated that in Washington, burial needs to take place at an official cemetery run by a corporation (Washington State Legislature, 2017).

The size of cemetery plots vary tremendously around the US. For this model, a rather small plot size was chosen as an average, as it reflects the growing need to use land more carefully within cities. According to the New York Times, a cemetery plot is about 213 x 76 cm, resulting in total area of 1.6 m^2 (St. John, 2003). To simplify the model, the land use of the cemetery facilities eg. chapel, roads, maintenance hub, is included in the land use by a single body. Therefore, it is assumed that burying a body occupies 3.6 m^2 of land.

Cremation

There are four distinct paths that cremated remains can take: the ashes can be buried at a cemetery in an urn, stored in an urn at a place of worship within the cemetery (columbarium), taken home by the relatives or can be scattered. Only the urns that remain at the cemetery contribute to the land use. Therefore, it is important to consider the percent of people opting for this practice.

The land use differs tremendously depending on whether the urn is buried or placed in a columbarium. Due to lack of precise information, it is assumed that burying an urn takes up 1m^2 of space. A Columbarium is a memorial wall with individual niches that can accommodate several urns on top of each other, thus using less space than burial. Again, due to lack of information it is assumed that an urn placed in a columbarium will require 0.2m^2 of space. This assumption is based on a columbarium with five urns stacked on top of each other (see Figure 23). According to the National Funeral Directors Association, of all people opting for cremation, roughly 36% are buried at a cemetery in an urn and 7% placed in a columbarium (NFDA, 2015).

Figure 23: Columbarium (Wikipedia, n.d.)

Resomation

Resomation practices are very similar to that of cremation. Resomation facilities are often located within the cemetery, similarly to crematoriums. It is assumed that the resomation facility takes the same amount of space as cremation, thus a burial of an urn with resomated remains occupies 1 m^2 of land. Respectively, a resomated body will occupy 0.2 m^2 when placed in a columbarium. The only real difference in modelling the two methods comes from the assumption that of the resomated bodies only 6% are opting for a memorial at the cemetery, and the rest is bringing the urn with them. More precisely, it is assumed that 4% of the resomated get buried at the cemetery and 2% placed in a columbarium. This assumption is based on an idea that the practice does not have a religious hold and thus placement of the remains to a place of worship seems less likely.

Green Burial

In green burial, the land is used less efficiently than in a traditional cemetery, because the restrictions of space are very limited. A green cemetery located in Washington State has plots of the size of 6 feet times 12 feet (182 cm x 368 cm = 6.7m^2) , which was taken as the base dimensions for the model (Moles Farewell Tributes, 2017). The company also states that the plots at the green cemeteries remain larger than in traditional burials not only due to the amount of space available, but also to foster sustainable absorption of nutrients into the land. However, it must be noted that in the model, the land use resulting from green burial is not accounted for towards the total land use, because the area of interest is land use within the urban area. The land occupied by green burial is located in the countryside, therefore decreasing the amount of land required for deathcare in the urban center. It is however interesting to include it in later discussion on environmental impacts of different methods.

Recomposition

Unfortunately, the information available on the dimensions of recomposition remains unknown as the recomposition facility does not exist yet. The size and procession capacity of a facility is based on assumptions by Dr. Troy Hottle. For this model it is assumed that the size of the Urban Death center totals 1600 m^2, and that a facility of this size can recompose 1 body per week, resulting in a capacity of 52 bodies per year.

Land already occupied by cemeteries

The City of Seattle stretches over an area of 83 square miles (214,969 km^2). The government of Seattle has detailed information on how the land is divided between different entities (Office of Planning and Community Development, 2015). Parks, open space and cemeteries together account for 9% of the total land: 19,347 km2. It is assumed that 10% of this category's land use, belongs to already occupied cemetery land. It is further assumed that a quarter of this land is occupied by cremation and the rest by burial. This is taken as the basis of land use for the model.

Scenarios under study

As stated before, the study includes a construction of three future scenarios with different mixes of funeral technologies.

Scenario 1

The Lock In

The current situtation of funeral technology advocation will lock in and remain unchanged from 2017 until 2100. In this scenario of the people of Seattle:

75,5 % get cremated
24,5% get buried

Scenario 2

The New Green Movement

Due to the growing impact of climate change in decision making, the funeral industry undergoes a change towards more environmentally concious technologies. In this scenario of the people of Seattle

25% get cremated
25% get green buried
25% get resomated
25% get recomposed

Scenario 3

The Paradigm Shift

The 21st century marks a paradigm shift in the funeral industry in Seattle: abandoning the traditional technologies of burial and cremation and embrasing the new technologies of resomation and recomposition. In this scenario of the people of Seattle:

30% get resomated
70% get recomposed

Figure 24: Presentation of the three scenarios

In Scenario 1: The Lock In, green burial and other niche technologies are not taken into consideration because of the lack of data on actual numbers and their marginal role. The goal of this scenario is to show the amount of land required in 2100 if Seattle continues with its current practices.

Scenario 2: The New Green Movement, is based on assumption that burial (the technology requiring most land use) will stop completely in Seattle, partly due to skyrocketing land prices. Instead, green burial and recomposition will take over as similar methods of burial in soil. The practice of cremation continues but is accompanied by resomation. Scenario 2 is characterized by embracing technological change accompanied with the advocation of the old methods.

In Scenario 3: The Paradigm Shift, it is assumed that recomposition will become the new norm in Seattle. Resomation is however still advocated by 30% of the population, mostly by people who want to take the remains home or scatter them in the nature.

One must keep in mind that beside Scenario 1, the other two scenarios have in reality no scientific evidence to be realized. It is important to realize that recomposition is not even legal yet. However, the purpose of these scenarios is to offer indication on how the new technologies might disrupt the established system and the role they could play in deathcare, as well as quantify the land use requirements of these technology mixes.

9.4 Results

The population of Seattle will grow from 668,400 in 2016 to 1,113,000 in 2100. Respectively, Seattle has to accommodate an increasing amount of deceased for the next decades. In 2017, 5481 people died in the area per year. By 2100, the number of deaths is predicted to increase to 9126. If all of the deceased people from 2017 to 2100 onwards would advocate the same deathcare technology, the differences in land use between the technologies would be drastic, as can be seen in Figure 25.

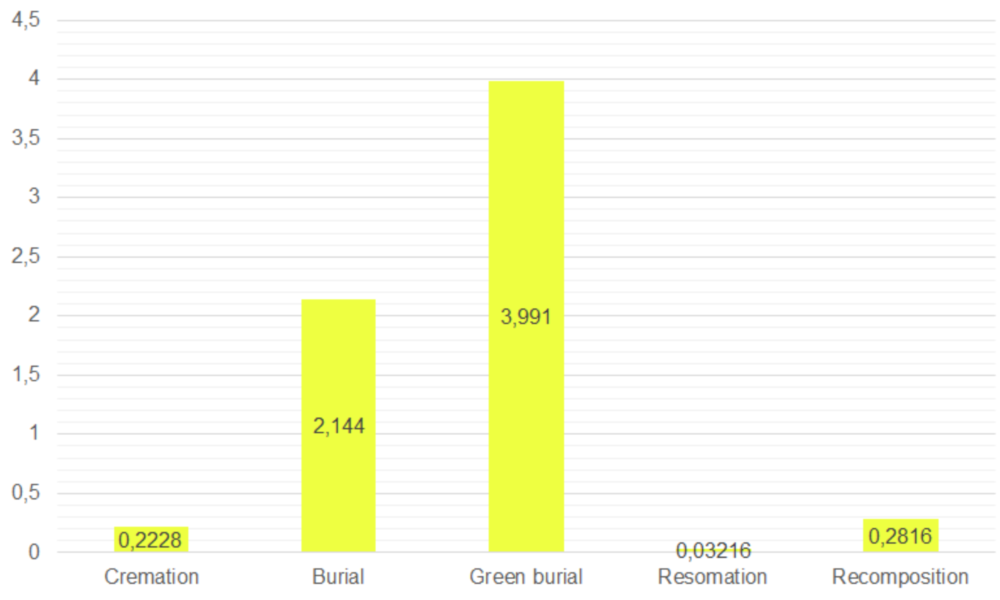


Figure 25: Land use per funeral technology

Traditional burial and green burial are the technologies with the largest land use. What must be kept in mind is that even though green burial has nearly twice the land use as traditional burial, this land use takes place in a rural rather than an urban setting. Cremation and recomposition require roughly the same amount of land, whereas resomation appears to have the smallest land requirement of all the technologies under study.

Out of the three scenarios, Scenario 2 performs the best, with Scenario 3 not far behind. As 1.93 km² of land is already occupied by cemeteries in Seattle, the total urban land use in 2100 does not show unexpected results. However, studying the numbers of new land occupation gives a much better start for comparison of the scenarios.

As the numbers presented in Table 9 and Figure 26 indicate, Scenario 2 would require only 20% of the land needed if the city continued with its present practices of 75,5% cremated and 24,5% buried. Scenario 3 would also only account 30% of current scenario. These results demonstrate that advocating the new funeral technologies, even in combination with the old ones, could lead to massive improvements of the deathcare system's land use in Seattle.

Table 9: Land use in the different scenarios

	Burial	Cremation	Green Burial	Resomation	Recomposition	TOTAL Urban Land Use	NEW Urban Land Use
The Lock In	1, 97	0,65	-	-	-	2,62	0,69
The New Green Movement	1,45	0,54	1,0	0,01	0,07	2,07	0,14
The Paradigm Shift	1,45	0,48	-	0,01	0,2	2,14	0,21

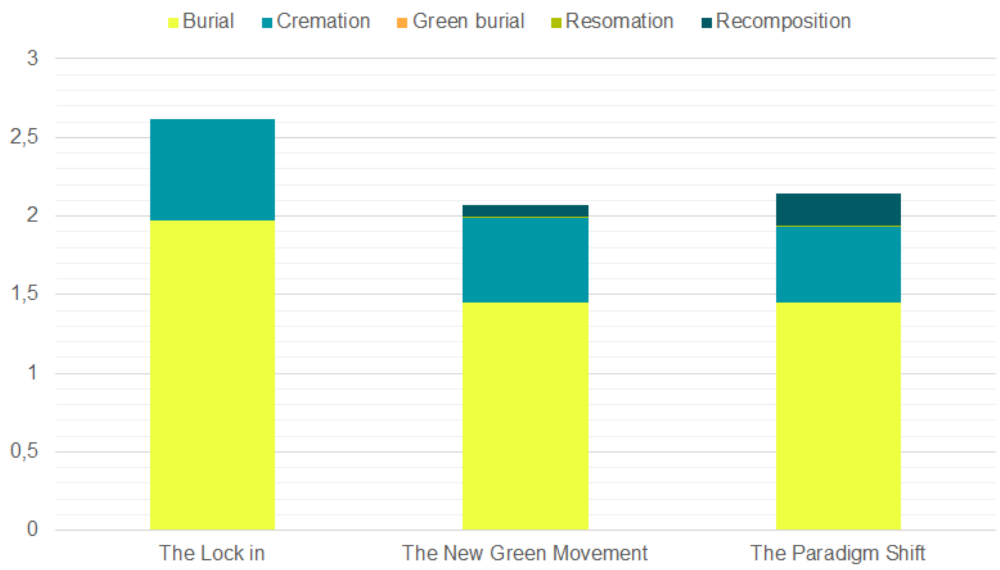


Figure 26: Land use in the different scenarios

9.5 Conclusion and discussion

The land use modeling highlights three important things: (1) in terms of land use, no current deathcare technology performs worse than burial, (2) not only the general funeral technology, but also individual choices determine the amount of land required and (3) the new funeral technologies have a potential of dramatically decreasing the land use required for funerals.

Unsurprisingly, burial performs the worst out of the five options studied in terms of land use. The final resting place practice makes its performance nearly ten times worse than cremation over the course of 83 years. If the Washington State continues without allowing the recycling of graves, the overcrowding of cemeteries will appear as a mass-issue sooner or later. There is a lot of space in the rural areas to advocate more green burial or to build complementary cemeteries, but this would come with its own set of issues, such as emissions due to longer transportation distances.

The results are strongly dependent on individual choices of placement of remains after cremation and resomation. Overall, it is more common to scatter the ashes or take them home rather than leave them at the cemetery, but these practice are subject to change. Overcrowding of cemeteries will most likely lead to an increase of the price of burial urns and columbariums, resulting in more people opting to take the remains with them. This would have a direct impact on the land use required by the cremation practice. Resomation remains even more uncertain, as the technology is still in development and therefore no information on the number of people opting for a memorial at the cemetery exists as of the writing of this report.

Among the three scenarios under study, tremendous differences in terms of land use can be found. Scenario 2: The New Green Movement, with 25% advocation of cremation, resomation, green burial and recomposition, performs the best with a land requirement of only 20% of that of Scenario 1: The Lock In. However, one must keep in mind that this scenario includes 1 km^2 land use by green burial which does not account towards the urban land use. If it would, the scenario would have the overall worst land use performance. This land use would take place at the rural areas outside of the metropolitan area of Seattle.

Recomposition and resomation could both contribute to solve the luring deathcare crisis and therefore, Scenario 3: The Paradigm Shift performs well, accounting 30% land use of that of the current scenario. Limited data about the size and procession capacity of the recomposition facility hinder the validity of the study. Improvements in the recomposition process could contribute positively to the land use performance. However, if the assumptions made for this study are too positive, the actual required land use could also drastically increase.

As Figure 27 demonstrates, the land requirements of the different technologies develop on their own distinguishable pace. Because recomposition renews its capacity to process bodies, the Paradigm Shift scenario specifically would require immediate occupation of large amounts of land to realize these facilities in the first place. The Paradigm Shift scenario would only start performing better than the

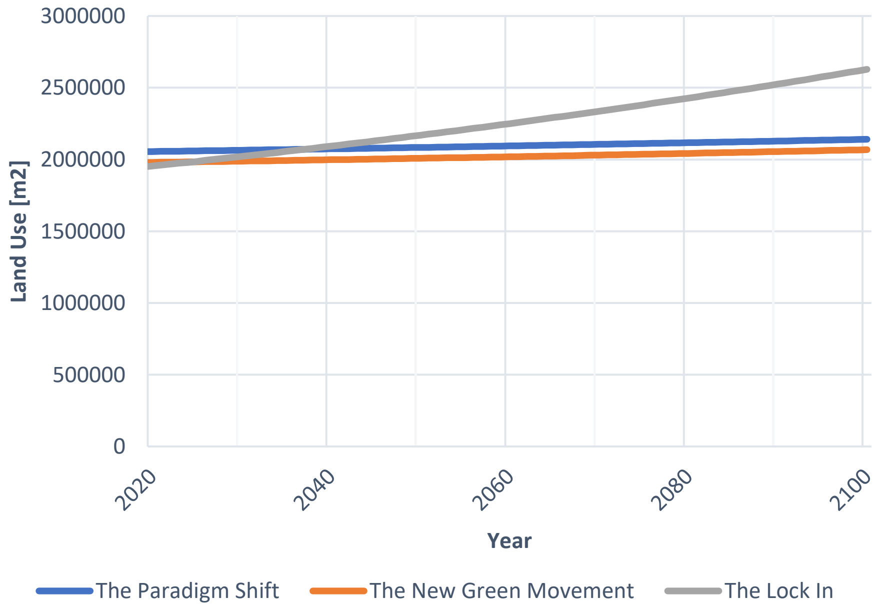


Figure 27: Development through time of the total land use by the different scenarios

Lock In, in terms of land use, after 2038. This might hinder the political support of recomposition as a technology, as people tend to make decisions based on short term gain and results.

9.6 Recommendations for future research

Overall, the results of the land use study are extremely uncertain and subject to change mostly due to system improvements/ failures and individual choices. For future research, it is encouraged to carry out another land use study on recomposition once the information concerning the facility and speed of the process are more definite. It would also important to study

Chapter 10 Emissions to the Environment

10.1 Introduction

In order to create a LCA model that allows for a fair comparison between the previously described deathcare alternatives, it is important that inputs are based on the same data. Keijzer & Kok (Keijzer & Kok, 2014) have previously worked on LCA studies for traditional burial, cremation, resomation and green burial using the same input data for substances from the human body. By adjusting this dataset to reflect the recomposition scenario, the uncertainty of the LCA analysis is limited. The research question defined to analyze these issues is as following:

What are the main emissions (to soil, groundwater, air) that can be expected during the composting of human remains?

Besides identifying emissions from the human body to the environment as input for the LCA analysis, further (literature) research was performed to identify potential problems the recomposition process could face. Finally, some recommendations are provided on how to potentially improve the system.

10.2 Methods

The data Keijzer has used to create the table of substances present in the human body on the moment of death is mostly based on research by Forbes (1987). Although his research is somewhat dated, it is still the most complete and referenced study in the field. In addition, two more elements were added based on other research to provide a more complete overview (Axelrad, Goodman, & Woodruff, 2009; Slooff, van Beelen, Annema, & Hanus, 1994).

As Keijzer mentioned in her 2014 report as well as in the conducted interview, it would be valuable to have data on the composition of the human body of this day and age. Mankind's behavior has changed significantly over the past decades, and it is imaginable that this has an impact on the composition of their bodies. It would be interesting to apply new data to this study if it were to become available.

Data on the emissions of traditional burial are taken as a benchmark. During burial, no additional processes affect the composition of the human body. All present matter ends up in the soil. The second relevant deathcare technology is resomation. In the resomation process, only the bones come out again. This is similar to recomposition, as bones (along with the other hard materials such as teeth and nails) take significantly longer to fully decompose. Because the recomposition process would not have time for this, bones and other undecomposed matter will be filtered out after the soft materials of the human body have decomposed. Therefore, by analyzing the remains after resomation, we know what elements end up in the soil during stage 1 of recomposition. This is the initial phase in which all soft tissues of the body are expected to be fully decomposed. The harder parts (like bones, nails and teeth) are further decomposed in stage 2. In reality, these processes may or may not be separate. After stage 1, sieving may occur and the harder parts can be moved to another composting facility or mixed again with in the same composting facility.

New information from the UDP suggests that both stages 1 and 2 can be completed within 8 weeks (personal communication with Hottle). It is important to note that stage 2 is not included in this analysis.

10.3 Results

Appendix D.1 depicts the elements of the human body that end up in the soil after being processed by various funeral technologies. The most right column provides the emissions to soil from the recomposition process that will be used in the LCA analysis. By utilizing data from traditional burial and resomation, the recomposition scenario can be modelled, similarly to resomation, only the bones remain after the process. All other components of the human body end up in the soil, from where the emissions may spread to air and water. However, the emissions to water will depend on the conditions in which the soil is used afterwards.

The recomposition column only takes stage 1 of the process into account. If stage 2 would also be taken into account, the totals would add up to the values provided in the burial column.

The ultimate goal of this study is to determine the emissions related to the recomposition process, which can be used in the LCA study in order to make an accurate comparison between recomposition and other funeral technologies. By using a landfill model, data on emissions to air, land and water that are critical for the LCA analysis can be collected. Not all elements that make up the human body were modeled in the landfill proxy process. Figure 28 provides an overview of the order of magnitude and inclusion/exclusion of all elements in the model.

From further literature research into the processes related to human decay, it was learned that this happens in several stages: Cadaveric decay, protein decomposition, decomposition of fat, decomposition of carbohydrates and decomposition of bone. Under influence of microorganisms and bacteria, many natural reaction processes take place that form new emissions. Each stage of decay is characterized by some of these processes. An overview is provided in appendix D.2.

The decomposition of the human body in soil is a very complex process, which can be subdivided in several key elements, as shown in appendix D.2. These are the main categories, there are several smaller groups that are not mentioned here due to their relatively low overall impact.

The 'input' is the body component that is being processed. The output are the substances that are created through these processes.

Unfortunately, the study this overview is based on Janaway, Percival & Wilson (2009) provides no numbers related to the emissions. It will therefore serve as a reminder of the background processes that make recomposition possible. It is a possibility to manually increase the efficiency of some of these processes to accelerate the overall speed of the decay process. Furthermore, specific flows or substances could potentially be tracked and captured to be either removed or used elsewhere.
An Excel-based landfill model was used as proxy for the emissions to soil, water and air as a result of 'landfilling' corpses. Landfilling was used as proxy for burial. The outcomes for recomposition are valid and can be compared on an equal level with the other funeral alternatives. Data from appendix D.1 was used as input in the model, and through processes described in appendix D.2, the final emissions were calculated by the model.

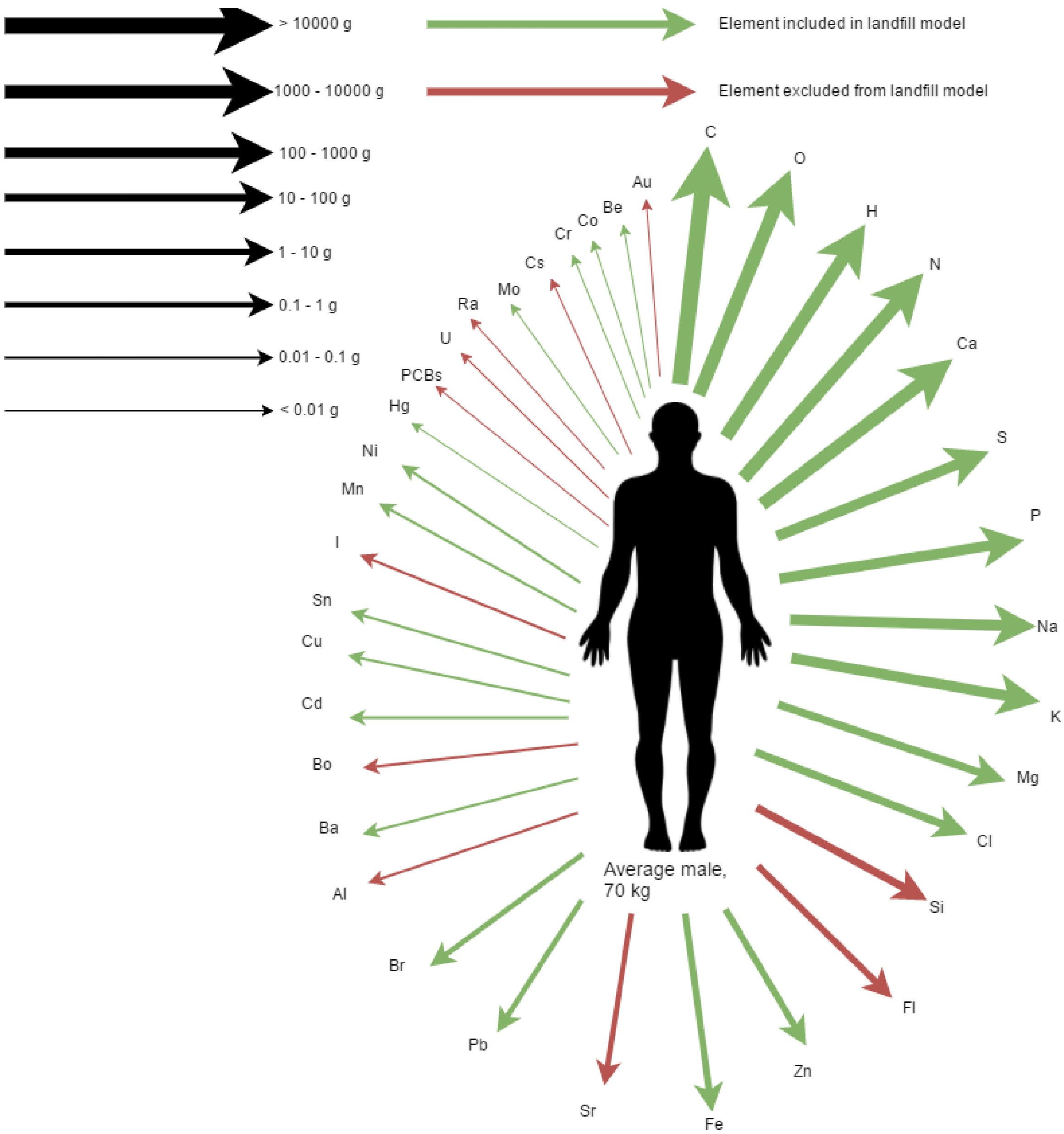


Figure 28: Elementary composition of the human body. Indicated in flows (g) and whether it is included in the landfill model or not.

Appendix D.3 shows the input data of the landfill model for all four funeral alternatives. Green burial is not specifically modeled, as the processing of the human remains is identical to that of traditional burial. It is important to note that the list of input elements is not as extensive as the list derived from literature (appendix D.1). This means that the impacts of the landfilling process in the LCA are lower than what would actually be the case. However, as all alternatives share this problem, the comparison is still fair.

Appendix D.4 depicts the emissions to air, water and soil as a result of landfilling human bodies. These emissions serve as direct input to the LCA model that will be discussed in the next chapter.

Worth noting is that the assumption is made that embalming is not required for bodies which will be processed through recomposition. This is legally already possible if there will be no viewing ceremony. However, if embalming fluids would have to be taken into consideration, its composition must be known. The composition Table 10 is based on research by O'Sullivan and Mitchell (1993), although it is aimed towards use for medical studies, which use more harmful materials. The data is still usable as a ‘worst case scenario’ guideline, in case embalming cannot be circumvented (Young, Blackmore, Leavens, & Reynolds, 2002).

Table 10: Content of embalming fluids

Component	Content
Formaldehyde	106 ml/l
Industrial Methylated Spirit	425 ml/l
Distilled Water	248 ml/l
Phenol	67 g/l
Glycerol	154 ml/l

It is worth noting that there are less toxic embalming fluids available, which are already being utilized in the green burial industry. However, no accurate data was found.

10.4 Conclusion and discussion

Reflecting upon the research question “*What are the main emissions (to soil, groundwater, air) that can be expected during the composting of human remains?*”, it can be concluded that the main emissions as a result of composting human remains in absolute values are 1.3 kg CO2 and 0.96 kg methane to air, 0.14 kg SO4, 0.52 kg PO4 and 0.18 kg N to water, and 0.016 kg PO4 to soil. However, as the table in appendix D.4 shows, there are many smaller emission flows dissipating into the environment. Although of smaller quantity, the relative impact of these flows could be bigger. This is taken into account in the LCA model.

The validity of the comparison between funeral alternatives is increased by using the same model and source of input data for each alternative. The work of Keijzer is among the most referred work within this field of study and she used a similar landfill model (personal communication with Keijzer). Data on the elementary composition of the human body used as input for the model also originates from the same source, which is unfortunately somewhat dated.

10.5 Recommendations for further research

As mentioned previously, the research on which the composition of the human body is based is fairly dated. The average human has become heavier, thus changing the composition of the body. New research on the exact composition of the human body, similar to the work of Forbes (as referenced to by nearly all sources in this field of study) would provide more accurate insights into the emissions to the environment as a result of composting human remains.

Further recommendations can be made based on literature about the general procedures of the decomposition process. There are some identifiable factors that increase the speed of the decomposition process. A high temperature, high moisture content and a coarse-texture of the soil (sandy) all have positive effects on the speed of decomposition of the corpse (Tibbett & Carter, 2008). Furthermore, the accessibility of oxygen to the body will also accelerate the process (Dent, Forbes, & Stuart, 2004). In the recomposition facility, oxygen is provided through the addition of wood chips, the alfalfa mix and water. Furthermore, air vents will be installed that refresh oxygen and control the temperature of the process. Due to the pressure and compact environment in which the decomposition process takes place, temperature stays relatively high without the need of external heating.

A risk that should be analyzed is the possibility of pathogens that were present in the body to spread through the soil. Generally speaking, a higher soil temperature will help to kill off microorganisms (twice as fast for every 10* Celsius increase between 5* and 30* Celsius). This aligns with the criteria for a fast decomposition process, which is beneficial for the UDP. Bacteria and viruses are also less likely to survive in soils with a pH above 7. Soil acidity can be changed manually, but usually involves chemicals with their own environmental impacts. Changing this variable is therefore not ideal.

The pore sizes in the soil greatly impacts the potential spread of microorganisms. Soils with small pore sizes, such as clay, have high adsorption capacities. This is something the UDP can look into, perhaps during future pilot studies.

Lastly, once the soil has left the facility, the amount of (rain)water reaching the soil and potentially carry microorganisms further down also plays a major role (Üçisik & Rushbrook, 1998). However, as the destination of the soil is unknown, this factor may be challenging to take into account. Ideally, the duration of eight weeks for the decomposition process is long enough to kill most pathogens that were present in the corpse.

If the compost that is produced during the recomposition process will indeed end up in a communal park of some sort, it is interesting to note that root network of nearby plants and trees will further decrease the spread of any pathogens that might still be left in the soil. As not all flora reacts to diseases the same way, a large diversity of plants is recommended (Uphoff, Ball, Fernandes, Herren, & Husson, 2006).

The advantage of the recomposition facility to decompose human remains is that it can operate in a closed system, where UDP has full control over input and output flows. Because of this, there may be possibilities to apply some sort of emission filters to capture emissions in the soil before they can spread to the environment through distribution of the soil. This is also the case for emissions to water, as prior to exiting the facility, the soil has not had any possibility to escape to groundwater levels. However, so long as UDP's plans for the facility are not finalized, it is assumed emissions can still reach (ground) water levels.

Chapter 11 Comparative life cycle assessment

11.1 Introduction

In the current day and age, the public awareness of environmental impacts of many industries, including the funeral industry, is ever growing. The last act on earth is often a polluting one. Different funeral technologies have different associated environmental impacts. Obviously, burial has issues with soil and ground water contamination and cremation with air pollution. As new funeral technologies enter the market, there is a need for a complete picture of all environmental impacts associated with the different technologies. Life cycle assessment (LCA) can provide such a picture, taking into consideration all aspects of preparation (e.g. embalming), auxiliary products (e.g. the coffin) and long term effects (e.g. processes in the ground).

Over the past few years, Dutch researcher Keijzer and colleagues have published three LCA studies on the potential environmental impacts of funeral technologies. The second report (Keijzer & Kok, 2014) was an update of a 2011 LCA study and looked at burial, cremation and resomation. The last report (Keijzer, 2016) focuses on burial and cremation alone and aimed to develop a benchmark for funerals.

The main findings of the research on environmental impact of different funeral technologies are that both cremation and burial have a relatively high potential environmental impact, compared to resomation. Impact assessment results of the comparative LCA study from 2014 are shown in Table 11. The impact assessment method used was the ReCiPe 2008 midpoint method.

Table 11: Characterized category indicator results from Keijzer & Kok (2014)

Impact category	Unit	Burial (average)	Cremation (average)	Resomation
Climate change	kg CO_2-eq	95	208	28
Stratospheric ozone depletion	kg CFC-11-eq	9.50E-06	2.20E-05	1.00E-05
Human toxicity	kg 1,4-DB-eq	-1	-55	-104
Photochemical oxidant formation	kg NMVOC	0.68	1.37	0.02
Particulate matter formation	kg PM_{10}-eq	0.26	0.36	-0.04
Ionising radiation	kg U^{235}-eq	16	13	18
Acidification	kg SO_2-eq	0.7	0.9	-0.2
Freshwater eutrophication	kg P-eq	0.17	0.19	0.06
Marine eutrophication	kg N-eq	0.25	0.53	0.01
Terrestrial ecotoxicity	kg 1,4-DB-eq	0.16	0.18	0.03
Freshwater ecotoxicity	kg 1,4-DB-eq	0.45	-0.12	-1.16
Marine ecotoxicity	kg 1,4-DB-eq	0.23	1.61	-1.15
Agricultural land occupation	m^2a	67	67	7
Urban land occupation	m^2a	138	3	1
Natural land transformation	m^2	0.03	0.04	0
Water depletion	m^3	11	10	5
Mineral resource depletion	kg Fe-eq	5	5	-21
Fossil fuel depletion	kg oil-eq	26	67	10

Resomation performs best in nearly all impact categories, except for ionizing radiation, which can be attributed to the production of the necessary chemicals. Although cremation performs slightly worse on most impact categories, burial performs much worse on urban land occupation (ULO). These impact category values cannot simply be aggregated, so no general conclusions about the comparative performance of burial and cremation can be drawn from this yet.

It is important to note that, while providing more insight, the results cannot be used to prefer one over the other. Contribution analyses are included in Keijzer & Kok (2014). She states that the main environmental impacts for both burial and cremation can be attributed to the manufacture, use and disposal of the coffin. This is followed by grave rest time and the monument (for the burial) and flue gas cleaning and cremation process (for the cremation). Remarkable is that resomation has a lot of negative values in terms of environmental impact from the resomation process, suggesting it actually has positive effect on the environment. This has to do with avoided burdens modelled in the LCA, mainly due to increased metal recycling rates in resomation.

Commissioner Troy Hottle from the Urban Death Project has extended the LCA of Keijzer (2011) with some process data on recomposition and made an LCA model in excel comparing burial, cremation (both with adaptations to better reflect the US situation), green burial and recomposition (Hottle, 2017). The first results show that that recomposition performs very well in the impact categories climate change and fossil depletion and most human and ecosystem health criteria. Recomposition performs less on cumulative energy demand and eutrophication, both of which can be attributed to the high amount of alfalfa mix required for the process.

It is important to notice that Keijzer found that additional activities related to the funeral carry by far the heaviest environmental burden (Keijzer, 2011). This can mainly be attributed to land use required for flowers, food and drinks and fossil fuel use for correspondence and funeral guests' transport. In the case of burial, the additional activities make up around 70% and in cremation, cryomation and resomation even up to 85 till 95%. This is an important consideration to keep in mind when interpreting the final results. Furthermore, Keijzer (Keijzer, 2011) found that compared to annual environmental impacts caused by a human, in some cases the funeral does contribute significantly (e.g. regarding SO_2 emissions) and in some case it contributes only little (e.g. regarding CO_2 emissions). In an admittedly morbid sense, dying is inherently sustainable and there is only so much you can do to improve your after-life environmental footprint. Still, there are many opportunities for making it even more sustainable.

11.2 Methods

11.2.1 Goal and scope of the study

The goal of this study is to extend and improve the LCA of Hottle (2017), to (1) provide insight in the main environmental issues related to different funeral technologies on the US market. (2) In particular, the aim is to provide insight in the main environmental hot spots of recomposition. (3) Furthermore, this LCA can be used to compare the environmental performance among alternatives. LCA as a method can provide insight into all three of these questions. As a guideline for the design and execution of the LCA, the Handbook on Life Cycle Assessment (Guinée et al., 2002) has been used.

The results can be used to identify areas of improvement and compare the alternatives based on their environmental impacts. Interested parties are the commissioner and actors involved in the funeral industry, including consumers looking for environmentally sound way of funeral. However, the study is not meant to be disclosed to the public since it does not comply with all ISO requirements for this. The study is commissioned by the Urban Death Project, based in Seattle, and carried out by students from the master program Industrial Ecology at the universities of Leiden and Delft in the Netherlands.

The funeral technologies of (traditional) burial, cremation, resomation, green (or natural) burial and recomposition are modelled in openLCA software. The aim is to create a flexible database in openLCA that includes many unit processes, which forms the basis for further analysis in the future. In this way, with few adaptations and limited work, the commissioner can continue to carry out LCA studies using updated process data. The analysis options of openLCA software are limited, but the program provides very useful contribution analysis options and is visually strong (flowcharts, graphs). Further analyses have been made in MS excel.

Various LCIA methods are implemented, the main being ReCiPe Midpoint (H) 2008. Normalisation has been done with global values from 2000 as a reference. Weighting has been done both by shadow prices and using the ReCiPe Endpoint (H) method. For elaboration on the selected shadow prices, please see the economic analysis (chapter 8). Data was gathered mainly from Keijzer & Kok (Keijzer & Kok, 2014), Keijzer (Keijzer, 2016) and Hottle (Hottle, 2017) and further extended with information from experts within the industry and scientific literature. The model has been made to reflect the US situation as accurately as possible. The database used was ecoinvent 2.2. This is released in 2010, so current state of technology is assumed to be reflected fairly well and should not affect the relative performance between technologies. All selected process data reflect the US situation where possible.

Since time is limited in this study project, some rough assumptions and calculations have been made. This is explicitly stated with the process data reporting and can be considered as starting points for improvement.

Function, functional unit, alternatives and reference flows

This study assesses the environmental impacts related to the provision of a funeral service by different technologies. Only processes directly related to the disposal of one human body are included. Auxiliary processes, related to e.g. the visitors of the funeral using transport, bringing flowers or drinking coffee, have been excluded. All process data are assumed to reflect the deathcare of one average male human of 70 kg.

The *function* therefore is to provide a funeral service to one average deceased person in the Seattle area. The *functional unit* is one funeral of an average deceased person in the Seattle area. The *alternatives* are funerals by traditional burial, cremation, resomation, green burial and recomposition. Based on these alternatives, the *reference flows* are:

1. Funeral of an average deceased person in the Seattle area by traditional burial
2. Funeral of an average deceased person in the Seattle area by cremation
3. Funeral of an average deceased person in the Seattle area by resomation
4. Funeral of an average deceased person in the Seattle area by green burial
5. Funeral of an average deceased person in the Seattle area by recomposition

For the main characteristics of the different funeral technologies, please see the overview in the consultancy report, chapter 1.3.

11.2.2 System description and inventory

11.2.3 System boundaries

The energy and material requirements for the disposal of one human body are modelled. Additional activities that are not directly related to the dead person (e.g. regarding visitors or remembrance) are outside of the system boundary.

Regarding the environment-economy system boundaries, resource extractions, land use and emissions are part of the environment. All goods and wastes used and produced are part of the economy. Agricultural production and controlled landfilling are included in the economy. Uptake of carbon by biomass is adapted directly from ecoinvent and further economy-environment boundary decisions are also dependent on ecoinvent methodology.

Water use in the recomposition system has for now been cut off, since no data on that has been found yet. For the same reason, refrigeration of the body up to the funeral has been cut off. This is assumed to be similar for all technologies, so it will not affect the relative performance. Any impacts of a person up to the point of death have been cut off, because this is not directly related to the funeral technology. Furthermore, since the model includes 5 funeral technologies, there was no time to go into much more depth and it is possible that some (minor) flows are missing.

11.2.4 Funeral technology flowcharts and process data

In order of the reference flows, the flowcharts will be presented (being burial, cremation, resomation, green burial and recomposition). The process data are reported chronologically, starting in the top left of the flowchart, moving to the bottom right (ending at the reference flow). If a process is used in multiple systems, like the shroud, it is reported only the first time. Environmental extensions are not sown in the flowcharts but can be found in the process data. The legend includes all elements of the flowcharts. Some foreground processes are drawn without the inputs, for the sake of clarity of the charts. Some clusters of related processes are drawn in the flowchart as one process (like different means of handling ashes after cremation), but are modelled as separate processes in the software and can be found in the process data description as such. Aside from that, the flowcharts directly represent the software model. Furthermore, additional descriptions can be found in the openLCA model, which is also delivered to the commissioner.

The process data for traditional burial, cremation an resomation have been taken from Keijzer & Kok (Keijzer & Kok, 2014) and adapted to the US situation. The adaptations are described in the tables (see appendix E.4) and calculations can be found below each table. For the green burial system, data from traditional burial were adapted to reflect the different situation. The adaptations were based on personal communication with René Poll, director of a green burial site in the Netherlands, a confidential report and own research. For the recomposition system, most data were taken from the LCA by Hottle (Hottle, 2017) and extended based on own research.

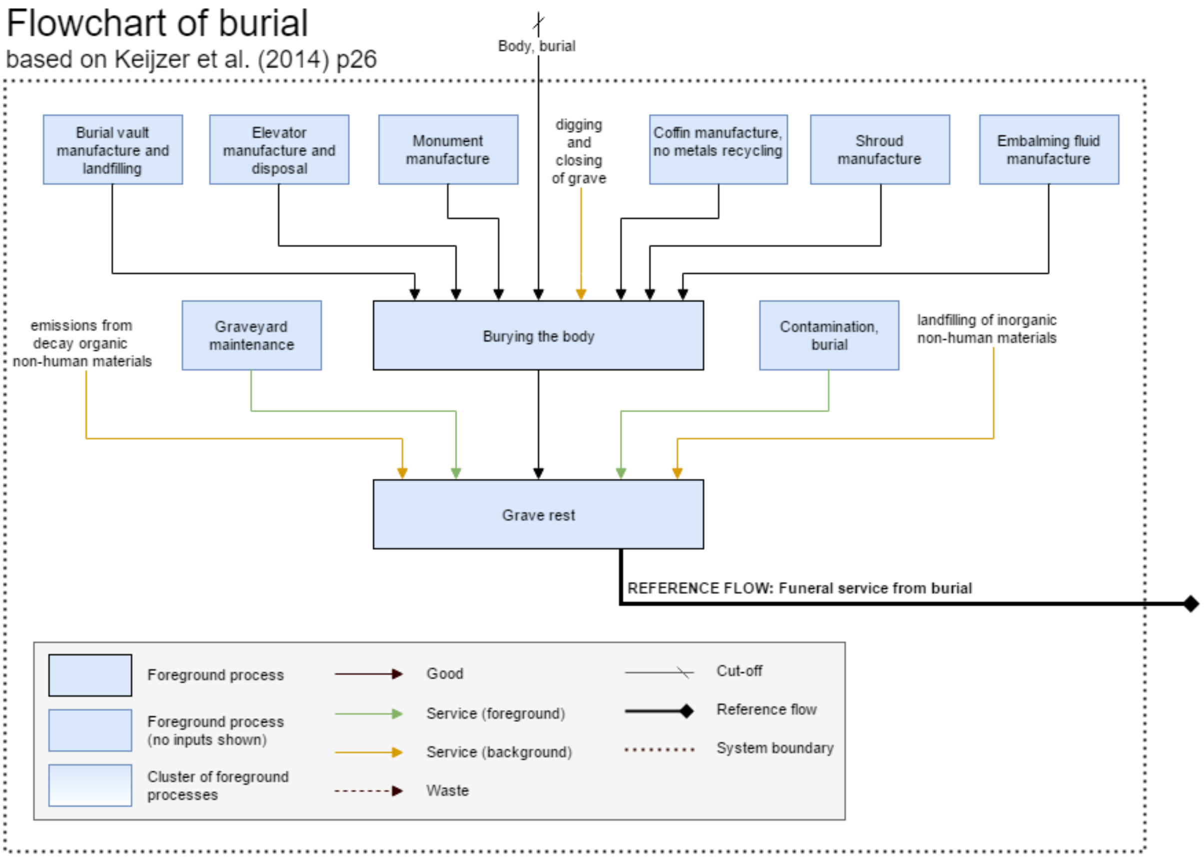


Figure 29: Flowchart of the burial system as modelled in this LCA

Burial

In traditional burial, the human body is buried in a cemetery. The body is placed in a shroud and in a coffin. A grave is dug using an excavation machine, the coffin is lowered into the ground (often using a simple elevator), the grave is closed and a monument is placed on top. In the US, the body is often embalmed with formaldehyde-containing embalming fluid and before closing the grave, a burial vault from reinforced concrete is placed on top. After the service, there is graveyard maintenance and emissions originating from the grave. Since in the US, a grave is an 'eternal' resting place, in theory there are infinite environmental impacts from graveyard maintenance and land use. It is very hard to model this in an LCA and therefore a time span of 500 years has been taken to represent an eternal resting place. The flowchart of the burial process is presented in Figure 29 and the process data and calculations can be found in appendix E.1.

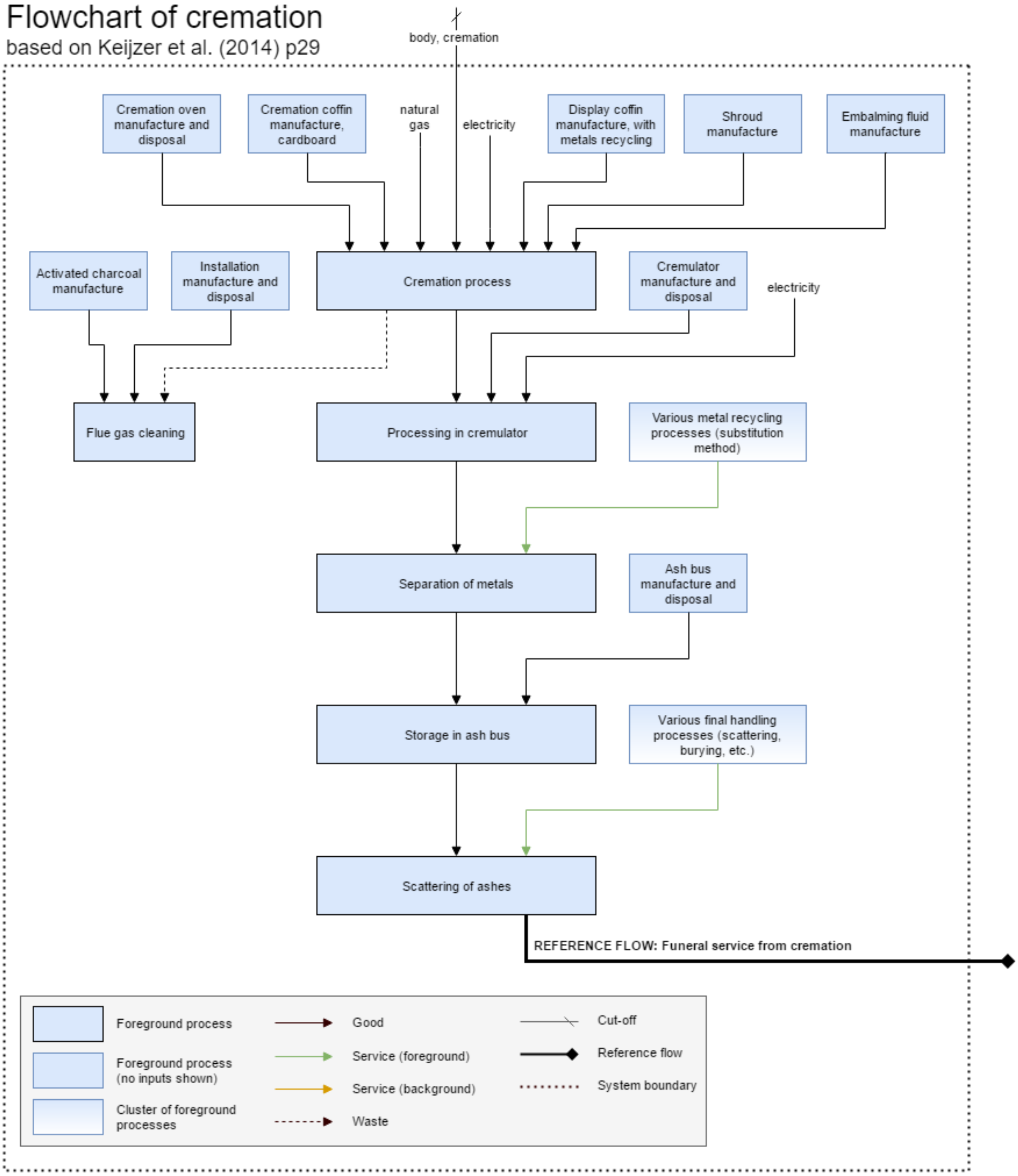


Figure 30: Flowchart of the cremation system as modelled in this LCA

Cremation

In cremation, the body is burned in a cremation oven using electricity and natural gas. In the US the body is burned is a different coffin than in which it is displayed. The cremation coffin is made out of cardboard and the display coffin is assumed to be reused 10 times (Keijzer, personal communication). Metal recycling is included. Embalming practices are assumed to be equal to burial. Flue gasses are cleaned using activated charcoal and the remains after cremation (bones and non-combustible non-human materials like prostheses) are separated. The bones are pulverized in a cremulator using electricity. In the Netherlands, ashes are stored for a mandatory 1 month in a special ash bus, before being transferred to the relatives. It is assumed that this is also the case in the US Finally, the ashes are kept in an urn at home, scattered over land or over sea, buried in an urn or stored in a columbarium. The flowchart of the cremation process is presented in Figure 30 and the process data and calculations can be found in appendix E.1.

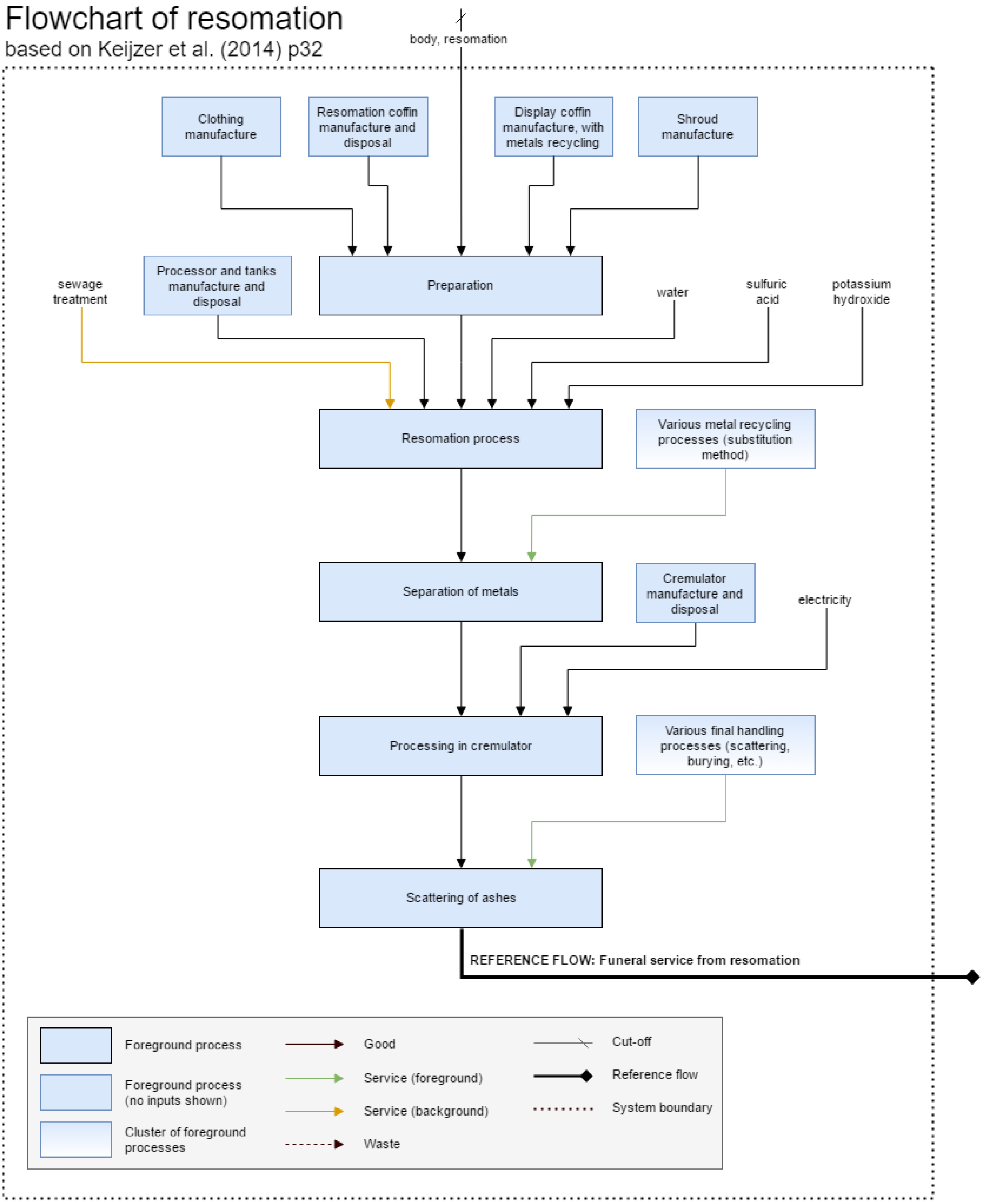


Figure 31: Flowchart of the resomation system as modelled in this LCA

Resomation

Resomation - also called biocremation or alkaline hydrolysis - is an innovative funeral technology where the body is dissolved in a strong basic solution, under high pressure and temperature. It is currently not legal in the Netherlands, but under discussion in the house of representatives (Yarden, 2017). In the USA, resomation is currently legal in twelve states (Tekle, 2016).

In resomation, the body wears cotton clothing and a special starch shroud. The coffin for display is assumed to be the same as for cremation. The coffin goes in the resomator in a special stainless steel coffin. The body is then dissolved using high pressure, high temperature, water, electricity and potassium hydroxide. After dissolving, the liquid is cooled and pH is balanced using sulfuric acid. The liquid with therein the dissolved soft parts of the body (flesh, intestines) are flushed to the sewer (WWTP class 5 assumed[1]), metals are separated and recycled and the bones are crushed, which is assumed to be a similar process as in cremation. Finally, the ashes are scattered. The scattering options are similar to the cremation system. However, a percentage of the relatives buries the ashes in a cardboard box to be composted.

Since resomation is perceived and presented to be a more environmentally friendly funeral method, it is assumed that no embalming fluid is used. Also, the percentage of relatives choosing to bury the ashes at the cemetery or storing it in a columbarium is assumed to be lower. Keijzer & Kok (Keijzer & Kok, 2014) assume reuse of prostheses. In this LCA, recycling is assumed, which is the same in cremation, resomation and recomposition. The flowchart of the resomation process is presented in Figure 31 and the process data and calculations can be found in appendix E.1.

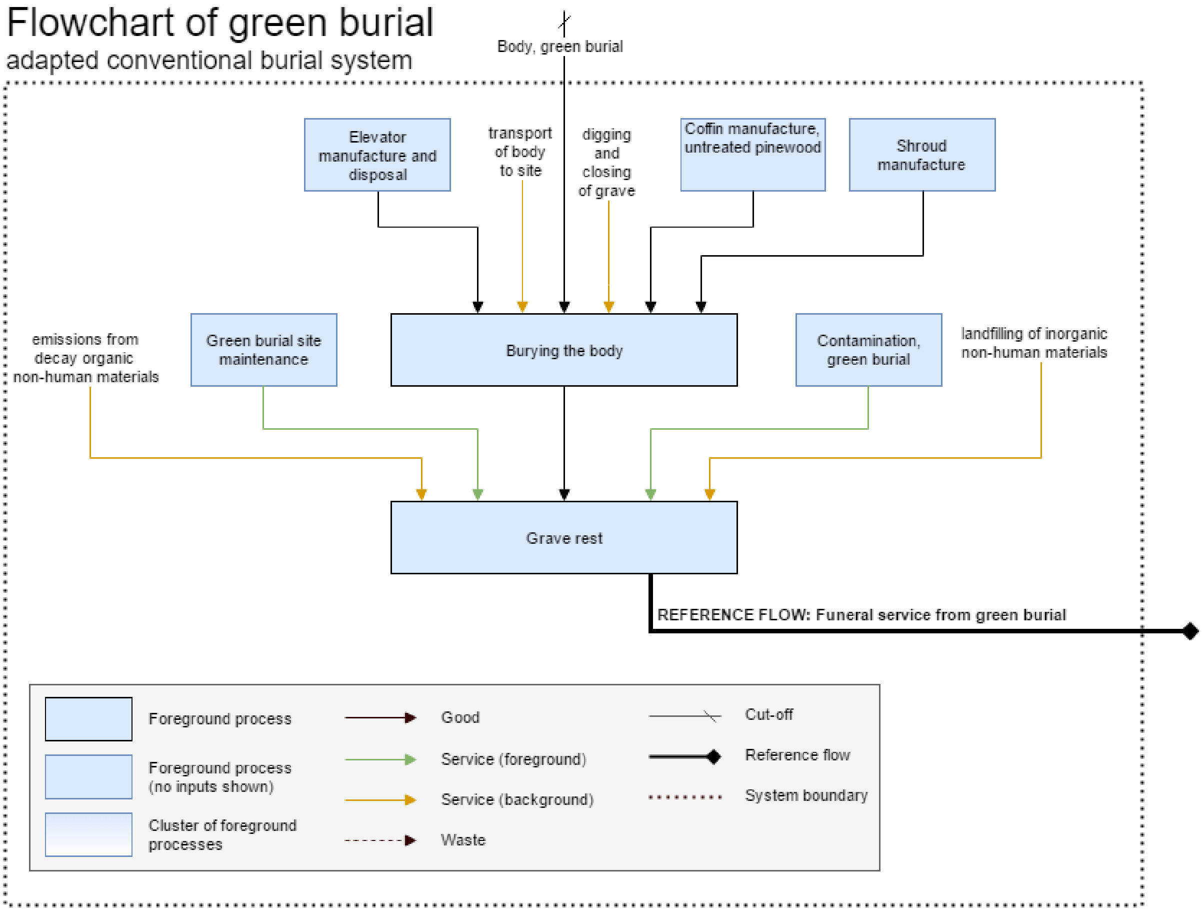


Figure 32: Flowchart of the green burial system as modelled in this LCA

Green burial

In green burial, the body is buried with reduced environmental impact. An untreated coffin is used in 90% of the time and an elevator in 10% of the time (Poll, personal communication). In some cases the body is even buried in only a shroud. The grave is dug less deep as in traditional burial. As a monument, a rock or a simple slice of a tree trunk is used. In some cases, formaldehyde-free embalming is offered, so that the body is allowed to be on display (Woodlawn Cemetery, n.d.). Green burial sites are located at the edge or outside the city. Therefore, a conservative additional transport of 30 km (back and forth)

[1] For classifications, see http://dec.vermont.gov/sites/dec/files/wsm/wastewater/docs/WWTORule_AppendixA.pdf

of the body to the green burial site is assumed. This reflects the distance to the nearest hybrid green burial/cemetery site in the Seattle area, the Woodlawn Cemetery. Maintenance of the site is assumed to be 75% less intense than in traditional burial.

In main lines this system is similar to traditional burial. However, especially regarding land use, this is a difficult technology to model. If it is to be a cemetery forever (like traditional burial), there will be land occupation and maintenance. If it will be a completely natural area at one point, the land occupation and maintenance will stop. Assumptions are very hard to make in that respect. In the Netherlands, the burial grounds are handed over to nature conservation authorities after 20-30 years once they are fully occupied. In the US, there are natural burial sites in nature as well as hybrid cemetery/natural areas. Details about similar business models as in the Netherlands have not been found. Therefore, in this LCA, the same period of land occupation as for traditional burial is assumed. In a sensitivity analysis this parameter is changed. The flowchart of the green burial process is presented in Figure 32 and the process data and calculations can be found in appendix E.1.

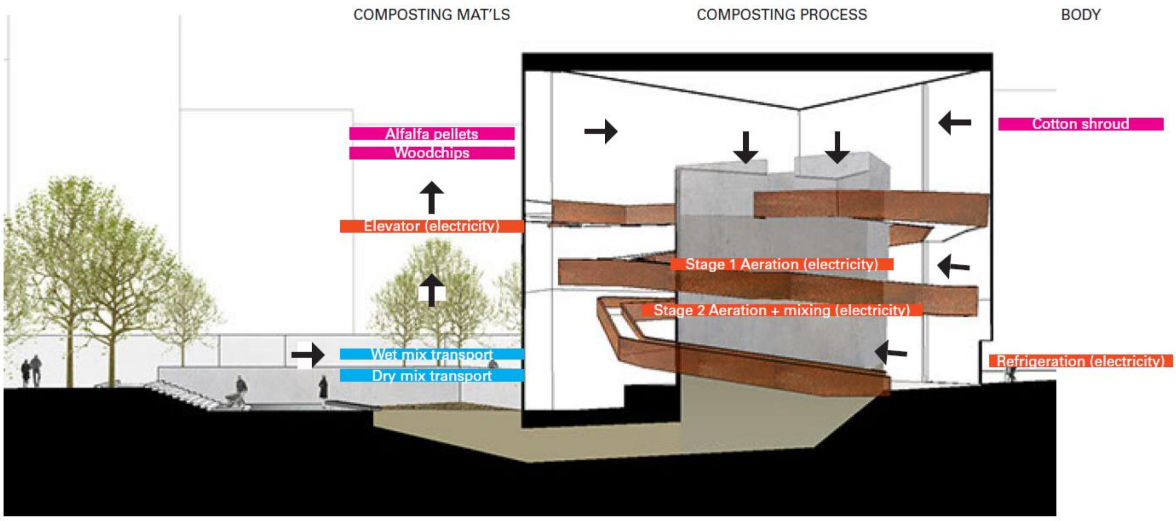


Figure 33: Diagram of the facility and main process steps of recomposition

Recomposition

In recomposition, the human body is composted with additional biomass in a special composting facility (see Figure 33). It is assumed that the body is kept in a display coffin before the recomposition process initiates. The body is then wrapped in a shroud, which is assumed to be the same as in the other technologies. With an elevator, the body is transported to the top of the facility where it is lowered on top of the composting pile. It is then covered with wood chips and alfalfa mix to start the composting process.

For the sake of modelling, two stages are discerned in the composting process. During stage one, the soft tissues decompose. With the current state of technology, around 500 kg of wood chips and 500 kg of alfalfa mix are added alongside the 70 kg human body. Residual wood chips from industry is assumed as a proxy and extensively produced hay are taken as proxies. It is assumed that first and foremost the UDP want easy and high quality wood chips and only later will look at ways to reuse waste materials. Changing the type of biomass input is the subject of a sensitivity analysis. Because no transport is included, transport for wood is also included in the process, which is taken from Hottle (Hottle, 2017). Water is added to reach the desired moisture levels. The bones take longer to decompose, which is modelled as the second stage of the composting process. The process is actively monitored using computers and sensors. Temperature is controlled by aeration and mixing, which uses electricity. At the bottom of the compost pile, heavy duty rolling stocks remove the finished compost from the facility. The compost is sieved to remove non-human materials and large parts. The latter can be placed back inside the facility to be composted further.

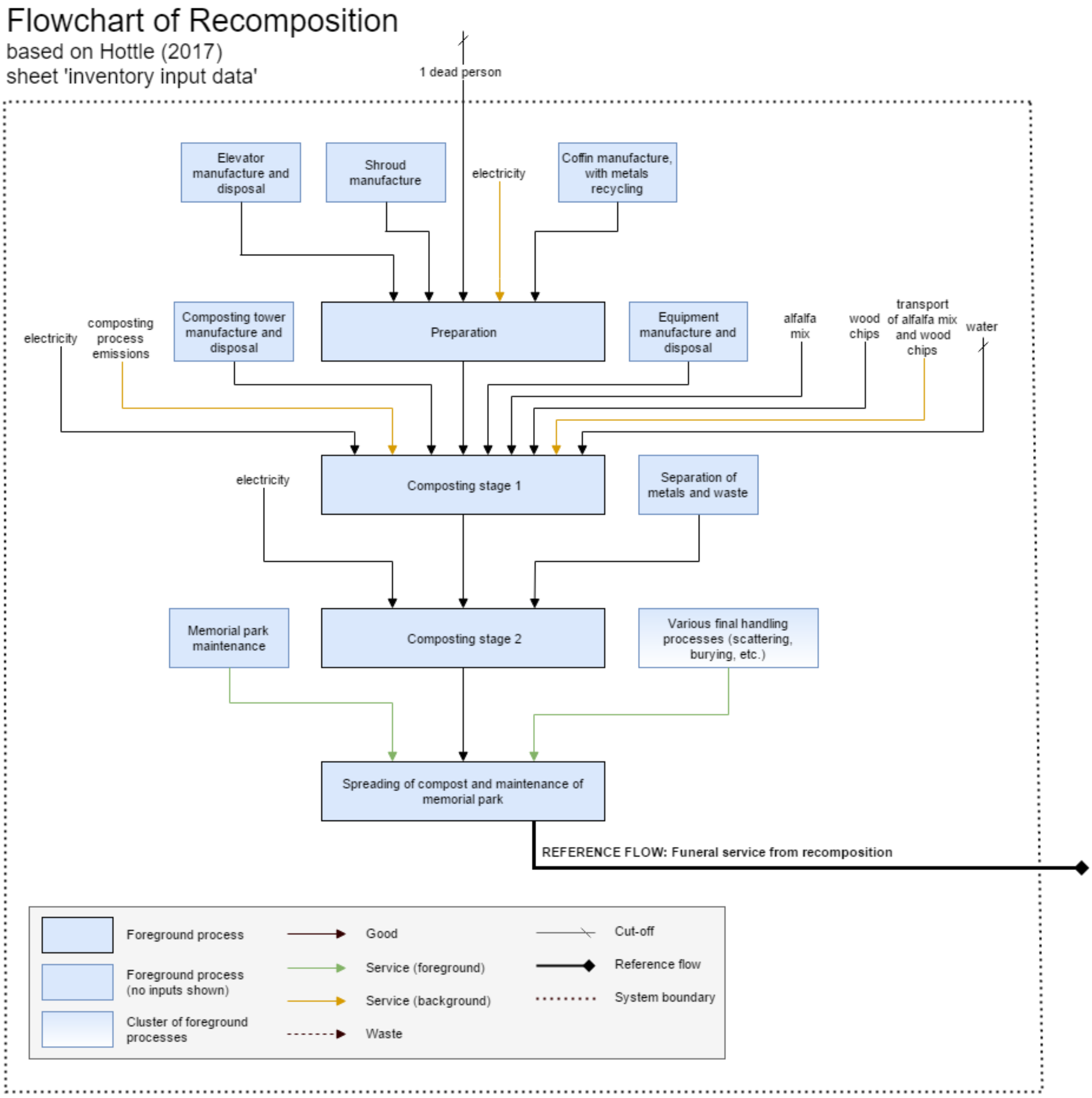


Figure 34: Flowchart of the recomposition system as modelled in this LCA

The composting process is aerobic, which means that mainly CO2 is formed. The compost conversion rate is 0.50 (Hottle, 2017), therefore half of the biomass input comes out as compost and half is released to the air (mainly as CO2). The emissions relating to composting the additional biomass are modelled with the ecoinvent process *compost, at plant* and the emissions related to composting the human body are taken from the emissions report (chapter 10). Please note that these were collected at a point where the composting stage 1 (decomposing the soft tissues) was assumed to be separate from stage 2 (decomposing the hard parts). This assumes the bones and teeth to be removed after stage 1. The emissions from composting are modeled in the composting process. The soil contamination is modelled in the compost spreading processes. The compost is assumed to be spread at the memorial park, at the home of relatives or spread outside the city, in the countryside.

The composting facility is placed in a memorial park, where some of the remains are spread and which serves as a place of remembrance. For the maintenance of this memorial park, maintenance requirements from the burial system are adapted. Here the annual requirements are divided by the number of people buried there to get requirements per person. This is very rough, but since there are no concrete plans yet for the memorial park, it is accepted as a proxy. 100 years of maintenance of a share of the memorial park is added to the recomposition system. This is a lot, especially since over time the number of deceased 'buried' in the memorial park is infinite. However, it is difficult to attribute a number. To not underestimate the burdens from the maintenance, the number is set at 100. The flowchart of the recomposition process is presented in Figure 34 and the process data and calculations can be found in appendix E.1.

11.2.5 Auxiliary processes

Pollution and contamination

At some point, elements contained in the human body are released to the environment. In the case of burial and green burial, this is over a long time span, while the body decays in the coffin or soil. Substances and elements are then released to the soil, leach into the groundwater and escape to the air. In the case of cremation and resomation, ashes can be scattered or buried, causing emissions to the soil and ground water. Another case is scattering over sea, where the ashes directly contaminate the sea water. In the case of recomposition, remains decompose and cause emissions to air, soil and eventually ground water. The chapter 'Emissions' explains how the numbers are calculated.

All emissions to soil are selected from the ecoinvent category 'Emission to soil/unspecified', to air 'Emission to air/high population density', to ground water 'Emission to water/ground water, long-term' and to sea water 'Emission to water/ocean'. If possible, the long-term option is chosen. Where possible, the normal element is selected, otherwise the ion is selected. Chemical Oxygen Demand for soil and Hydrogen in the sea are left out because no flows were found. All are modelled as flows out of the process, together with the total amount of contamination, all emissions combined. For the contamination tables, see appendix E.1.

Missing metals in ecoinvent

Three metals that are used in the LCA are missing in the ecoinvent 2.2 database. These are stainless steel with a certain percentage secondary metal content, chrome-cobalt steel for prostheses (only needed for the recycling) and titanium. The latter has been modelled by taking process data from the ecoinvent 3.3 database and modelling it in the LCA. For this, titanium tetrachloride production had to be modelled as well. For process data, see appendix E.1.

Metals recycling

An influential factor in the LCA by Keijzer & Kok (Keijzer & Kok, 2014) is the metals recycling, even causing negative environmental impact in some cases. The metals recycling is modelled by avoided burden, meaning the recovery of the metals avoids primary production. The avoided burden is modelled in openLCA by selecting the avoided production as an output and checking the box for 'avoided product'. The process data is taken from Keijzer & Kok (Keijzer & Kok, 2014). Average initial secondary content of metals, for which there is no avoided burden, is included. Furthermore, a recycling process efficiency of 90% is assumed. Many secondary metals and specific recycling process burdens are not available in ecoinvent, in which case a proxy is taken. For all recycling processes a distance for collection of recycled metals of 10 km is assumed, because scrap metal can be collected by Pacific Iron & Metal in the centre of Seattle. For process data, see appendix E.1.

11.3 Results

In this report, only the ReCiPe (H) impact assessment (mid- and endpoint) is shown. Results from other impact assessment methods are obtained from openLCA, but not further analysed here. They can be found in appendix E.6.

11.3.1 Results per impact category

Characterized results

Table 12 shows the characterized results of all systems under study using ReCiPe Midpoint (H) 2008 impact assessment method in openLCA. The positive values represent environmental impact in that category. The negative values represent an environmental benefit. In this LCA, environmental benefits originate from metals recycling, which avoids the production of virgin metals.

Table 12: Characterized category indicator results

Characterized category indicator results						
Impact category	**Burial**	**Cremation**	**Resomation**	**Green burial**	**Recom-position**	**Reference unit**
Agricultural land occupation	0.00	0.00	0.00	3350.00	0.00	m2*a
Climate Change	192.65	190.97	148.33	52.74	272.45	kg CO2 eq
Fossil depletion	57.73	28.45	41.71	17.95	31.95	kg oil eq
Freshwater ecotoxicity	2.98	1.96	0.33	1.89	-0.21	kg 1,4-DB eq
Freshwater eutrophication	0.22	0.91	0.14	0.18	0.00	kg P eq
Human toxicity	69.93	117.87	-25.65	22.74	-56.65	kg 1,4-DB eq
Ionising radiation	61.91	28.89	47.46	5.11	19.60	kg U235 eq
Marine ecotoxicity	1.60	2.78	-0.10	0.46	-0.88	kg 1,4-DB eq
Marine eutrophication	0.26	0.19	0.20	0.20	0.56	kg N eq
Metal depletion	19.25	39.64	-14.56	1.34	-11.81	kg Fe eq
Natural land transformation	0.00	0.00	0.00	0.00	0.00	m2
Ozone depletion	0.00	0.00	0.00	0.00	0.00	kg CFC-11 eq
Particulate matter formation	0.42	0.16	0.19	0.08	0.36	kg PM10 eq
Photochemical oxidant formation	0.97	0.34	0.36	0.22	0.84	kg NMVOC
Terrestrial acidification	1.14	0.29	0.57	0.29	1.60	kg SO2 eq
Terrestrial ecotoxicity	0.20	0.07	0.07	0.09	0.08	kg 1,4-DB eq
Urban land occupation	1800.00	0.31	0.73	0.00	0.00	m2*a
Water depletion	834.36	456.20	568.79	69.98	246.02	m3

Relative results

The comparative results are presented in Table 13. Here a relative comparison is made, using the highest (most impactful) category score as 100%. Colour coding is used to increase the readability. Please note that this concerns the relative performance between the systems under study per impact category. It does not say anything about the relative environmental burden between impact categories.

Table 13: Comparative results using relative scores

Relative scores (largest = 100%)					
Impact category	**Burial**	**Cremation**	**Resomation**	**Green burial**	**Recomposition**
Agricultural land occupation	0%	0%	0%	100%	0%
Climate Change	71%	70%	54%	19%	100%
Fossil depletion	100%	49%	72%	31%	55%
Freshwater ecotoxicity	100%	66%	11%	63%	-7%
Freshwater eutrophication	24%	100%	15%	20%	0%
Human toxicity	59%	100%	-22%	19%	-48%
Ionising radiation	100%	47%	77%	8%	32%
Marine ecotoxicity	57%	100%	-4%	17%	-32%
Marine eutrophication	47%	34%	37%	36%	100%
Metal depletion	49%	100%	-37%	3%	-30%
Natural land transformation	0%	0%	0%	0%	0%
Ozone depletion	100%	52%	30%	28%	44%
Particulate matter formation	100%	39%	44%	20%	84%
Photochemical oxidant formation	100%	35%	37%	22%	86%
Terrestrial acidification	71%	18%	36%	18%	100%
Terrestrial ecotoxicity	100%	36%	36%	42%	39%
Urban land occupation	100%	0%	0%	0%	0%
Water depletion	100%	55%	68%	8%	29%

Table 14 illustrates how often each of the technologies was either the best or worst alternative for an impact category. Equal scores are counted for all technologies with the same score. Burial clearly has the worst environmental performance of all. Green burial most often has the lowest impact. Remarkable is that resomation nowhere has the lowest impact. Recomposition and cremation seem to be in between.

Table 14: Amount of times that alternatives have either the best or worst performance in an impact category

Funeral technology	**Best performance**	**Worst performance**
Burial	2	9
Cremation	6	4
Resomation	6	0
Green burial	10	1
Recomposition	7	3

From these results it would seem that recomposition performs average compared to the other funeral technologies under study. Green burial and resomation both seem favorable to recomposition and burial and cremation have a higher environmental impact. The relative scores are graphed in Figure 35. The impact categories where recomposition performs worst are climate change, marine eutrophication and terrestrial acidification. Furthermore, it performs badly in the categories fossil depletion, particulate matter formation and photochemical oxidant formation (summer smog). It performs best in land occupation and transformation, freshwater ecotoxicity, freshwater eutrophication, human toxicity and marine eutrophication. It also performs well in metal and water depletion.

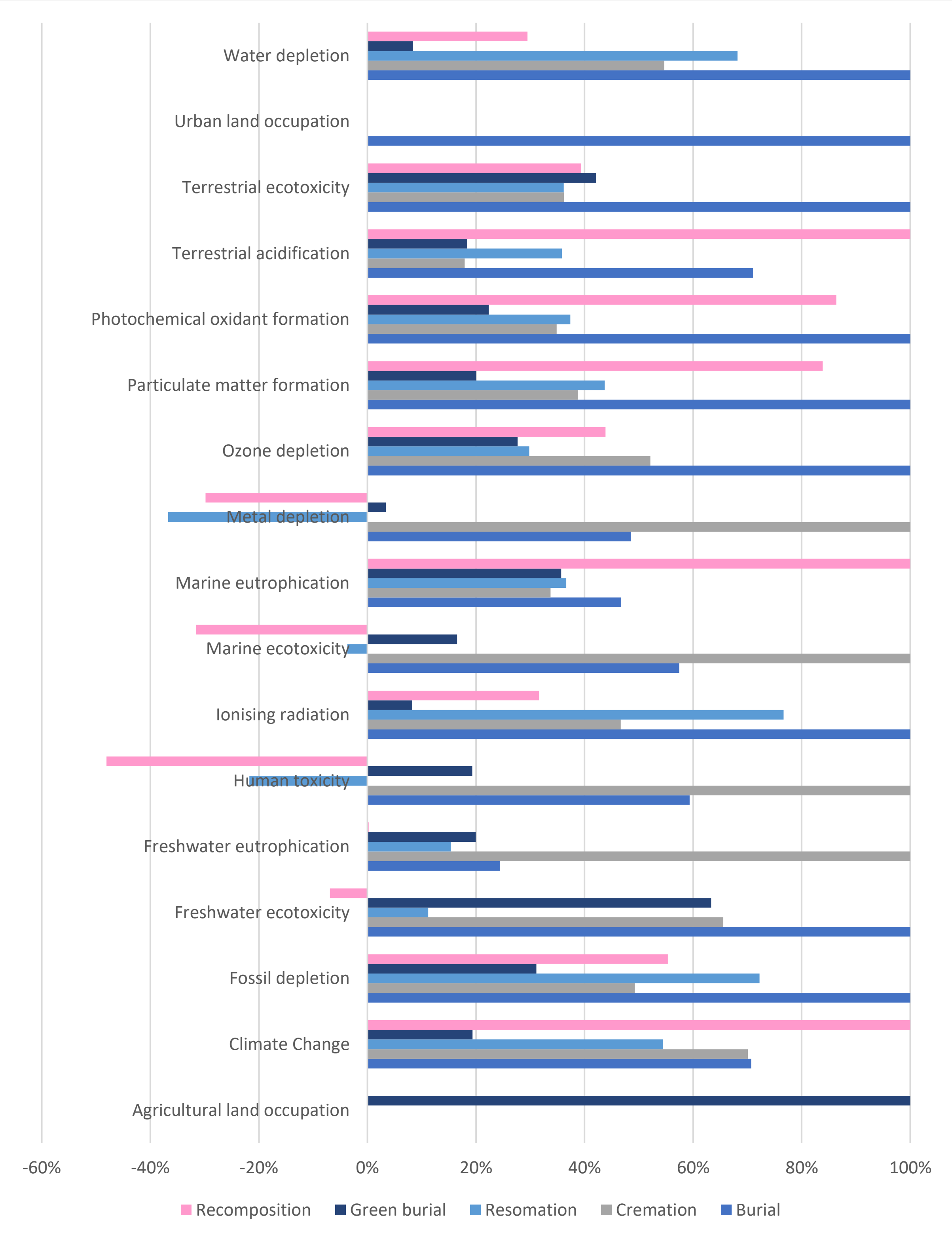


Figure 35: Comparative category indicator results relative to highest

Normalized results

In normalization, the category indicator results are compared to a certain reference. In this report, the global category indicator results from the year 2000 are taken. Therefore, the scores represent the environmental impact compared to the (estimated) yearly global impact of human activity in that category. The unit therefore is year and the higher the score, the more that environmental impact can be seen as a point of concern. Normalization values are taken from World, 2000 as a reference. The results are shown in Table 15.

Table 15: Normalized category indicator results (reference: World, 2000)

Normalized category indicator results (reference: World, 2000)							
Impact category	**Burial**	**Cremation**	**Reso-mation**	**Green burial**	**Recom-position**	***Reference: World, 2000***	**Unit**
Agricultural land occupation	0.00E+00	0.00E+00	0.00E+00	1.01E-10	0.00E+00	3.32E+13	Year
Climate Change	4.57E-12	4.53E-12	3.52E-12	1.25E-12	6.46E-12	4.22E+13	Year
Fossil depletion	7.31E-12	3.60E-12	5.28E-12	2.27E-12	4.05E-12	7.90E+12	Year
Freshwater ecotoxicity	1.13E-10	7.42E-11	1.27E-11	7.16E-11	-7.84E-12	2.63E+10	Year
Freshwater eutrophication	1.26E-10	5.14E-10	7.88E-11	1.03E-10	1.26E-12	1.77E+09	Year
Human toxicity	3.50E-11	5.90E-11	-1.28E-11	1.14E-11	-2.84E-11	2.00E+12	Year
Ionising radiation	7.68E-12	3.58E-12	5.88E-12	6.33E-13	2.43E-12	8.07E+12	Year
Marine ecotoxicity	1.06E-10	1.85E-10	-6.80E-12	3.05E-11	-5.83E-11	1.51E+10	Year
Marine eutrophication	5.82E-12	4.20E-12	4.55E-12	4.44E-12	1.24E-11	4.49E+10	Year
Metal depletion	7.06E-12	1.45E-11	-5.34E-12	4.92E-13	-4.33E-12	2.73E+12	Year
Natural land transformation	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.36E+10	Year
Ozone depletion	1.05E-13	5.49E-14	3.14E-14	2.92E-14	4.62E-14	2.30E+08	Year
Particulate matter formation	4.93E-12	1.91E-12	2.15E-12	9.85E-13	4.13E-12	8.61E+10	Year
Photochemical oxidant formation	2.78E-12	9.71E-13	1.04E-12	6.23E-13	2.41E-12	3.47E+11	Year
Terrestrial acidification	4.87E-12	1.23E-12	2.46E-12	1.26E-12	6.86E-12	2.34E+11	Year
Terrestrial ecotoxicity	5.63E-12	2.04E-12	2.04E-12	2.37E-12	2.21E-12	3.63E+10	Year
Urban land occupation	3.79E-10	6.63E-14	1.54E-13	0.00E+00	0.00E+00	4.75E+12	Year
Water depletion	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	Year

It is critical to keep in mind that normalization values are highly debated, especially for toxicity impact categories. Therefore, these results should be regarded with some reservation. The results from the normalization step are shown in Figure 36. The categories of natural land transformation, water depletion and ozone depletion have been excluded because there are no results, no reference value or very low results respectively.

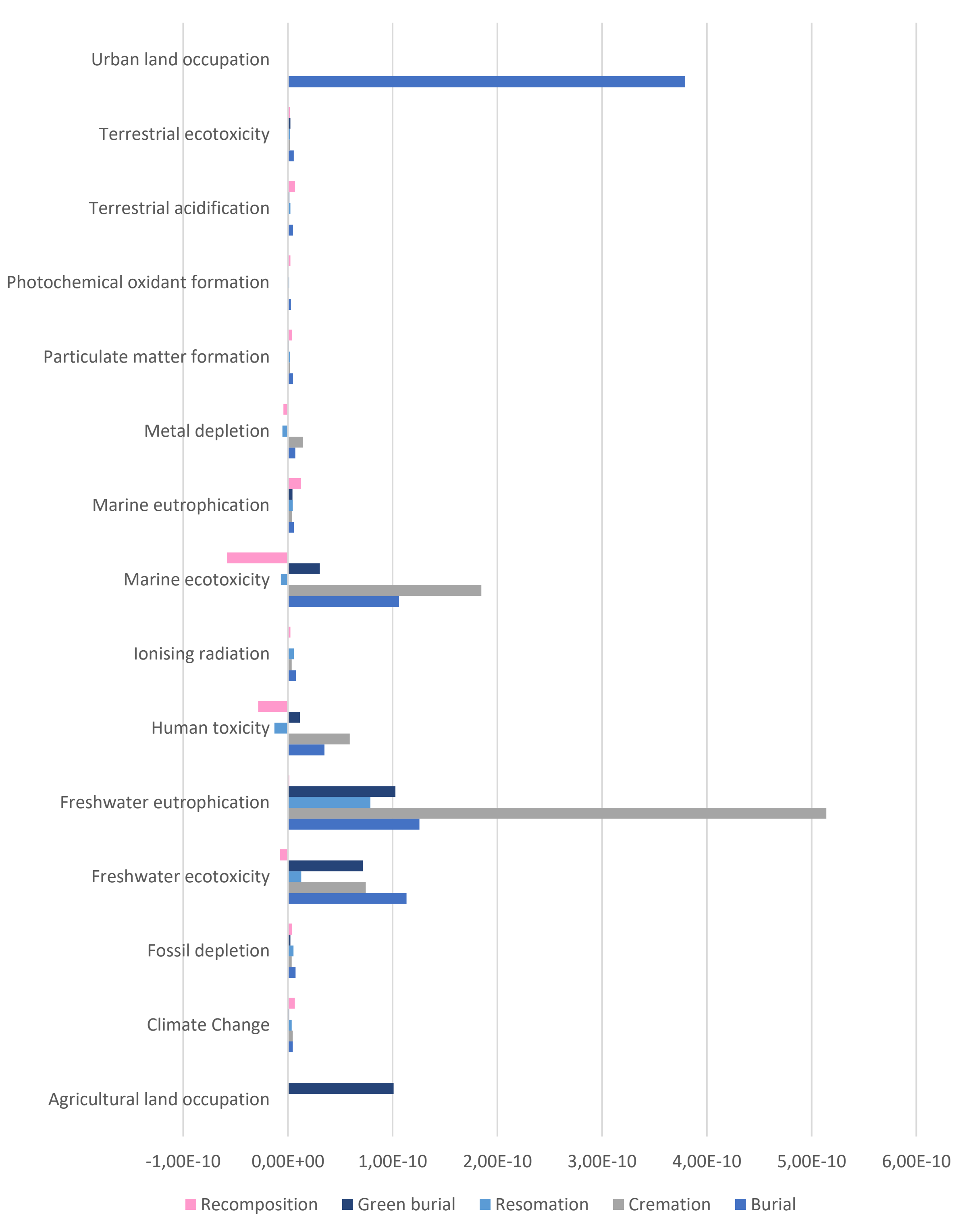


Figure 36: Normalized category indicator results (reference: World, 2000)

Judging from this graph, urban land occupation, marine ecotoxicity, human toxicity, freshwater eutrophication, freshwater ecotoxicity and agricultural land occupation are the impact categories of greatest concern for the funeral technologies in general. The impacts standing out from the crowd are urban land occupation for traditional burial (to be expected) and freshwater eutrophication for cremation. A contribution analysis in openLCA shows that the high values for eutrophication can be attributed to the scattering of the ashes from cremation, which contain large amounts of phosphorus (see the emissions report, chapter 10).

Another conclusion from the normalized results is that none of the positive peaks (thus signifying negative effect on the environment) are related to recomposition. Even more, recomposition seems to perform best in each of the impact categories of greatest concern. This means that when looking at the funeral industry as a whole, the main environmental impacts are caused by the other funeral technologies. If the goal is to make the (inter)national funeral sector more sustainable, it seems best to either increase the market share of the lesser impactful technologies (recomposition in particular) or improve the environmental performance of the other technologies (especially burial and cremation).

Isolating the recomposition results provides insight into the main categories of concern for that technology. The results are presented in Figure 37.

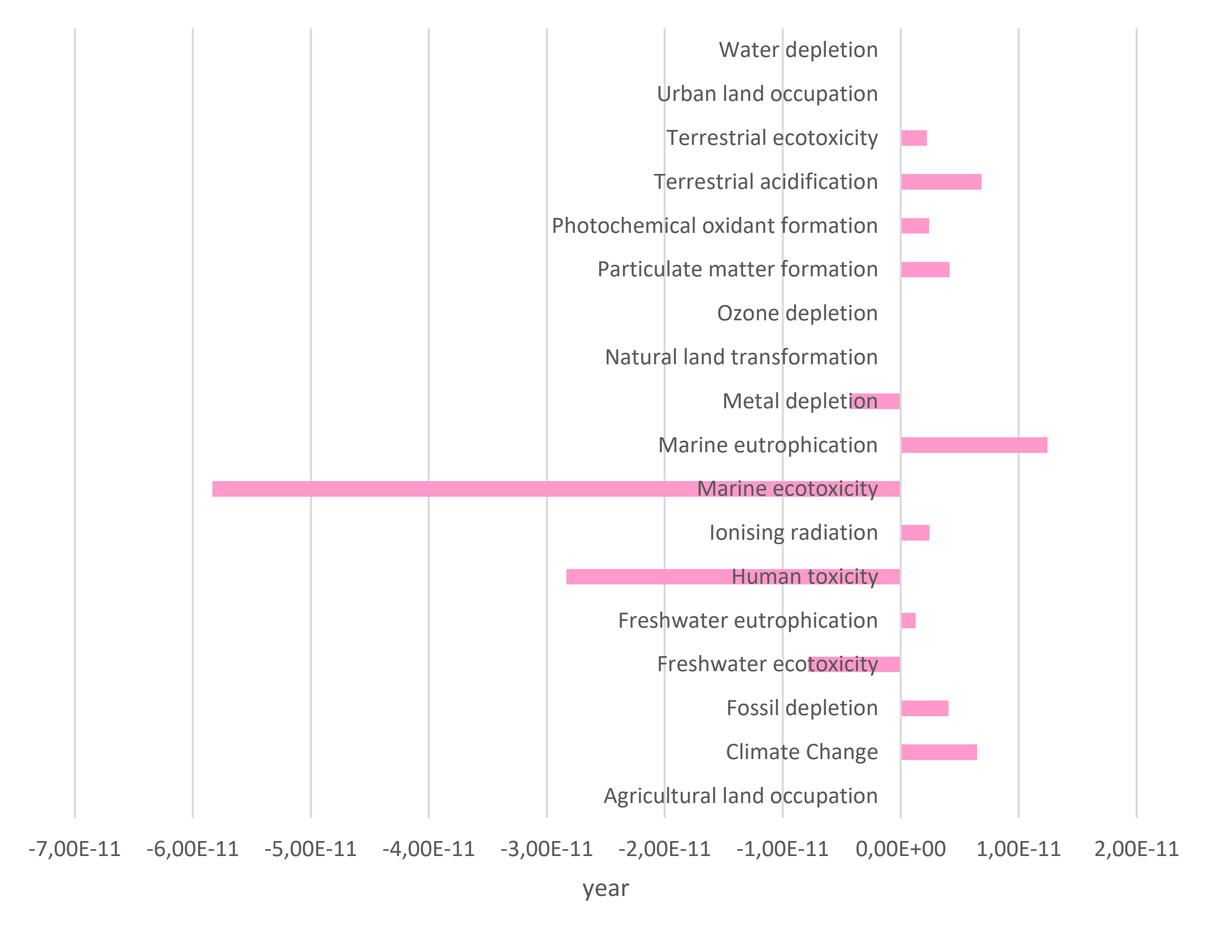


Figure 37: Normalized category indicator results for recomposition (reference: World, 2000)

Marine eutrophication, terrestrial acidification and climate change are three categories that form the main areas of concern. Furthermore, fossil depletion and particulate matter formation deserve attention. The environmental performance can be improved by improving processes that have the highest impact in these areas. The paragraph about the contribution analysis shows which processes contribute most to these impact categories. Nevertheless, it must again be stressed that normalized results can give a distorted view, and only provide part of the picture.

Weighted results

In the weighting step, impact categories are assigned a subjective preference (on top of normalization). If for example, climate change is judged to receive higher priority than acidification, the score of climate change will be higher. One method of weighting is to include shadow prices. This is based on the projected societal costs for prevention or mitigation of environmental impacts and it is therefore expressed in a currency (€ in this case, see Table 16).

Table 16: Weighted results using shadow prices

Weighted results using shadow prices							
Impact category	**Burial**	**Cre-mation**	**Reso-mation**	**Green burial**	**Recom-position**	**Shadow price (€/reference unit)**	**Reference unit**
Agricultural land occupation	0.00	0.00	0.00	314.90	0.00	0.094	m2*a
Climate Change	4.82	4.77	3.71	1.32	6.81	0.025	kg CO2 eq
Fossil depletion	0.00	0.00	0.00	0.00	0.00	0.000	kg oil eq
Freshwater ecotoxicity	0.12	0.08	0.01	0.08	-0.01	0.040	kg 1,4-DB eq
Freshwater eutrophication	0.40	1.62	0.25	0.32	0.00	1.780	kg P eq
Human toxicity	1.47	2.48	-0.54	0.48	-1.19	0.021	kg 1,4-DB eq
Ionising radiation	2.60	1.21	1.99	0.21	0.82	0.042	kg U235 eq
Marine ecotoxicity	0.00	0.00	0.00	0.00	0.00	0.000	kg 1,4-DB eq
Marine eutrophication	3.27	2.36	2.56	2.49	6.99	12.500	kg N eq
Metal depletion	0.00	0.00	0.00	0.00	0.00	0.000	kg Fe eq
Natural land transformation	0.00	0.00	0.00	0.00	0.00	0.002	m2
Ozone depletion	0.00	0.00	0.00	0.00	0.00	39.100	kg CFC-11 eq
Particulate matter formation	21.84	8.47	9.55	4.37	18.31	51.500	kg PM10 eq
Photochemical oxidant formation	0.57	0.20	0.21	0.13	0.49	0.585	kg NMVOC
Terrestrial acidification	0.73	0.18	0.37	0.19	1.02	0.638	kg SO2 eq
Terrestrial ecotoxicity	0.26	0.09	0.09	0.11	0.10	1.280	kg 1,4-DB eq
Urban land occupation	169.20	0.03	0.07	0.00	0.00	0.094	m2*a
Water depletion	834.36	456.20	568.79	69.98	246.02	1.000	m3

The prices for water depletion are very high. This is because in in the openLCA IA method pack, much more flows were classified in this category than prescribed by ReCiPe 2008. The reason is unsure, but the shadow prices for water depletion completely obscure the others in these results. Therefore, water depletion is left out of the graph (see Figure 38 and Figure 39). Please take caution in interpreting the prices for land use, as these are subject to debate in this model.

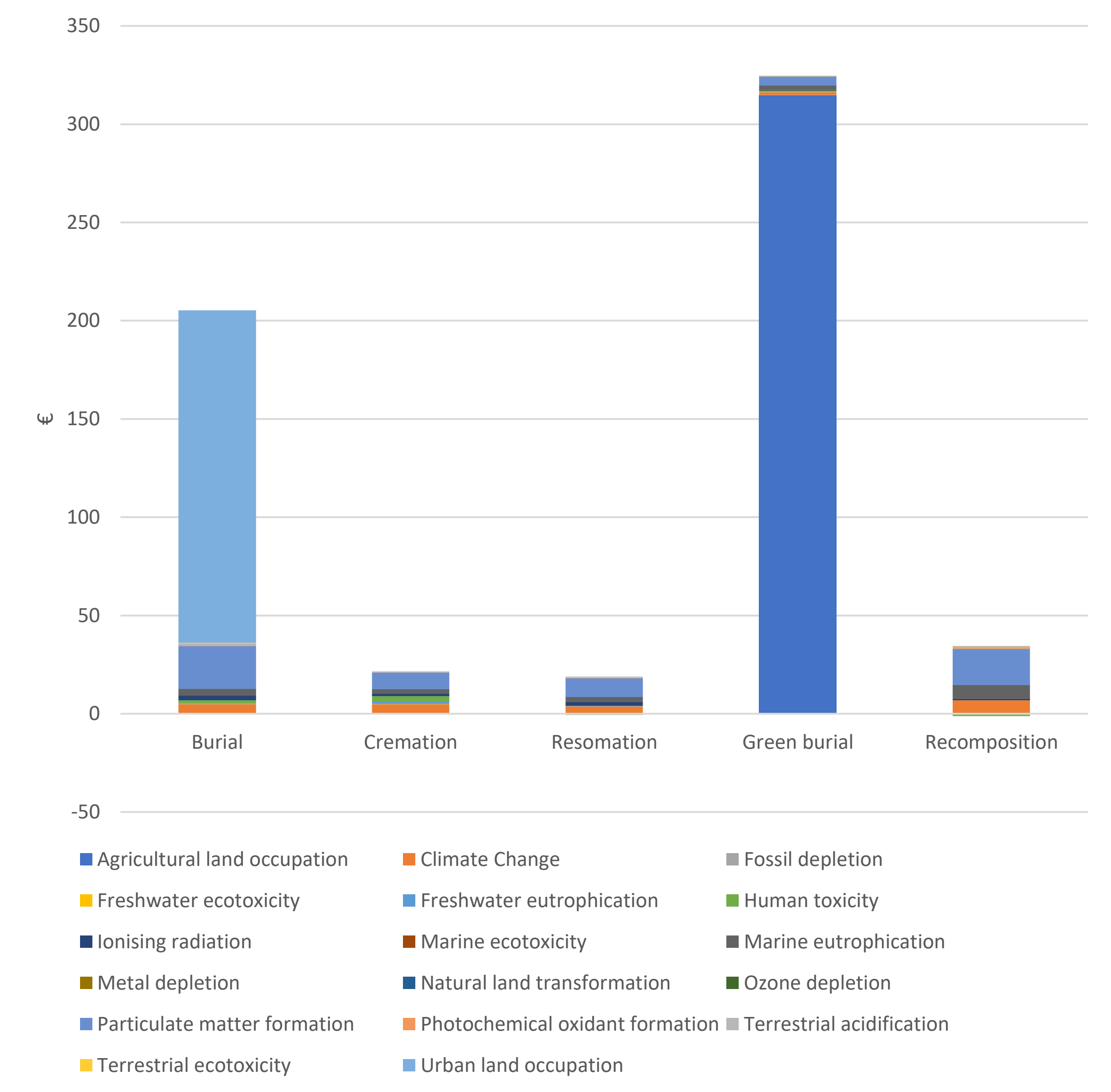


Figure 38: Shadow costs of the burial alternatives, excluding water depletion

Burial and green burial both have very high shadow costs due to the land occupation. Because the US provide an 'eternal' resting place for the remains, the shadow costs are infinite in theory. This also goes for cremation and resomation, which have a small amount of land use due to burying of the urn in the cemetery or in the columbarium and scattering the ashes in a designated field on the cemetery. The land use of green burial especially is a point of discussion. In the current results, a time span of 500 years has been taken to represent this 'eternal' resting place, resulting in the high environmental impacts and shadow costs. The influence of assuming a different time span is explored later on in sensitivity analysis 1 (chapter 11.3.3).

Looking at the shadow costs of recomposition, the main areas of concern seems to be particulate matter formation, followed by marine eutrophication and climate change.

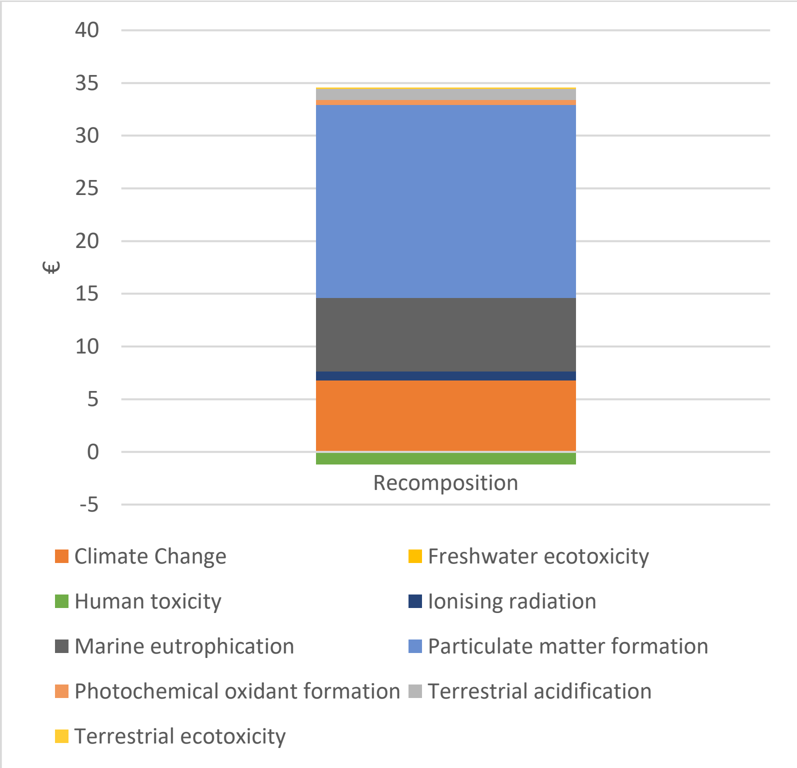


Figure 39: Shadow costs of recomposition, excluding water depletion

11.3.2 Contribution analysis recomposition

The recomposition system can be divided in six stages:

- Preparation: Includes the manufacture of the coffin, shroud and energy requirements for transporting the body and additional biomass to the top of the column.
- Composting process: Includes the energy requirements of the composting process, as well as the compost emissions.
- Spreading of compost: Includes the soil and ground water contamination of the compost and the transport of it.
- Building and maintenance of facility and park: Includes the material requirements of the facility and its equipment and the material and energy requirements for maintenance of the memorial park.
- Additional biomass for composting: Includes the cultivation, processing and transport of the wood chips and alfalfa mix used in the composting process.
- Recycling of metals: Includes the process requirements and environmental benefits (avoided virgin production) of metals recycling.

The results are presented in Figure 40 (see appendix E.7 for more detail). The preparation has a relatively small influence on all impact categories except terrestrial ecotoxicity, which can mainly be attributed to the production of the cotton shroud used and the pesticides involved. It is useful to explore (organic) alternatives for cotton.

The composting process has a relatively high environmental impact, especially in the categories of terrestrial acidification, photochemical oxidant formation, particulate matter formation, ionizing radiation and climate change. The main drivers are the emissions to air methane, dinitrogen monoxide, ammonia and nitrogen oxides. The carbon dioxide emitted during composting is not linked to climate change in ecoinvent, because it is considered biogenic CO_2. By reducing CH_4 and N_2O emissions of the process (in ecoinvent assumed to be 10 g and 0.28 g / kg compost respectively), the impact on climate change could significantly be reduced. Particulate matter formation is mainly driven by ammonia and to a lesser extent by nitrogen monoxides. Terrestrial acidification is caused by ammonia. Reducing ammonia emissions could therefore significantly reduce the former two category indicator scores. The ionizing radiation is caused by electricity from nuclear power, which is used in the electricity mix by the compost plant. This could be avoided by switching to more sustainable sources of electricity.

The spreading of the compost includes contamination caused by the human body. It has relatively low impacts in most categories, except for terrestrial ecotoxicity (due to chlorine), marine eutrophication (nitrogen) and freshwater ecotoxicity. It is therefore useful to measure whether chlorine levels of the soil reflect levels assumed in this study (see the emissions report, chapter 10) and adapt where necessary. The building and maintenance of the park has relatively low influence overall.

Additional biomass for composting contributes significantly to most impact categories, with the exception of toxicity impact categories. In this model extensive hay farming is used as a proxy for alfalfa mix production. It is likely that the results in toxicity categories would be higher if biomass from intensive farming (using more pesticides) was used. Nitrate is the main cause of marine eutrophication and phosphate of freshwater eutrophication. The origin flows of the impacts in other impact categories are too dispersed to follow to the source, but are all related to farming practices and the fuels, chemicals, electricity, etc. used. The sheer quantity of farmed biomass causes it to contribute so heavily in most impact categories.

The recycling of metals has a rather high environmental benefit, counteracting environmental impacts of the process and in some cases even causing environmental gains. It is thus important that this is a part of the recomposition process.

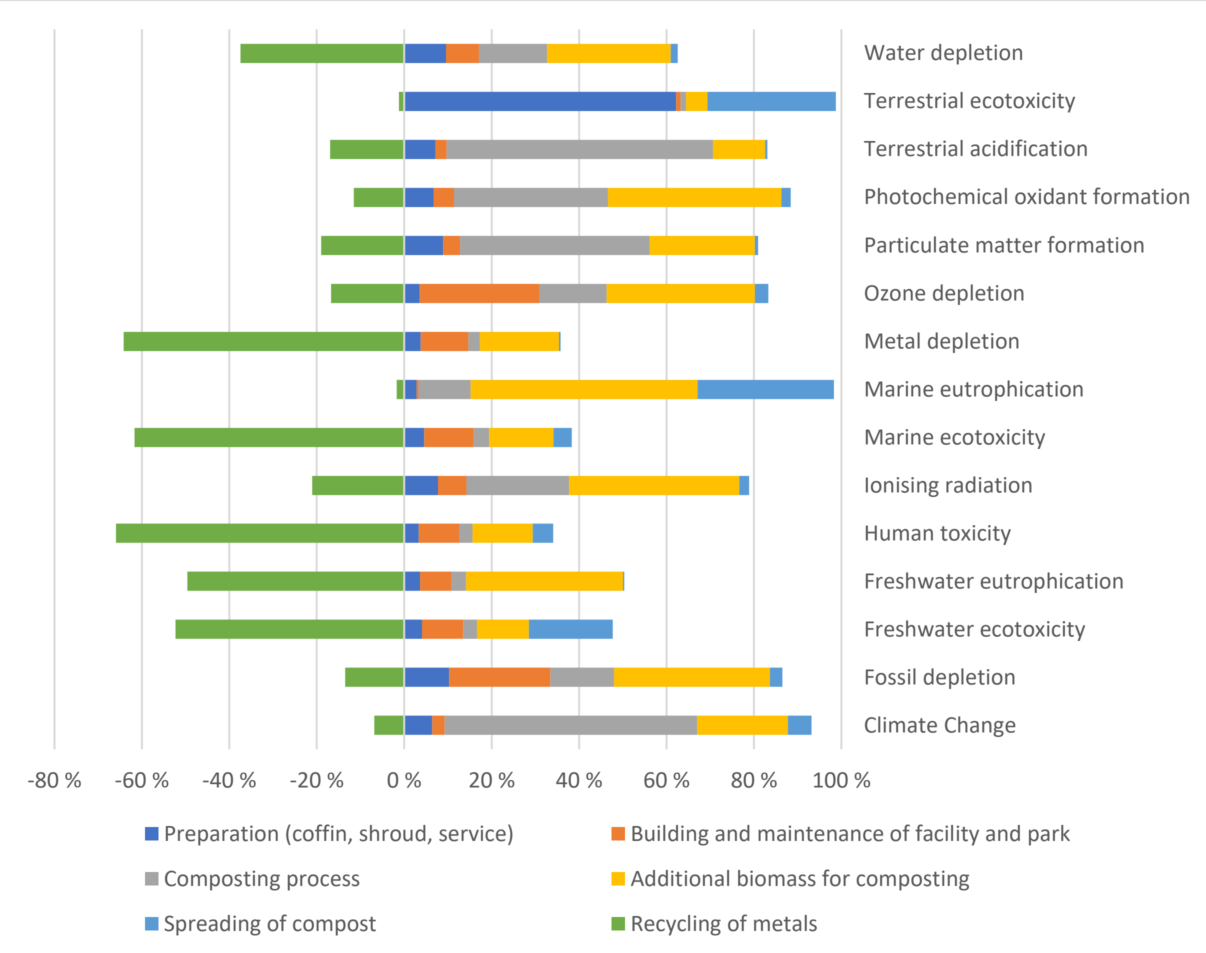


Figure 40: Contribution analysis for each of the stages of recomposition

Figure 41 shows the contribution analysis for the main areas of concern that were identified in the normalization and weighting steps: terrestrial acidification, particulate matter formation, marine eutrophication, fossil depletion and climate change. As discussed previously, the composting process and the production of additional biomass contribute the most and should thus be studied in more detail. The fuels used in the machinery for maintenance of the memorial park contributes a lot to fossil depletion and thus switching to machinery that does not use fossil fuels could reduce impacts there. The nitrogen in the compost is the cause of marine eutrophication. It might be a good idea to look into ways to apply the compost where nitrogen is used as efficiently as possible. Finally, it is worthwhile to look into more sustainable alternatives than the conventional cotton shroud.

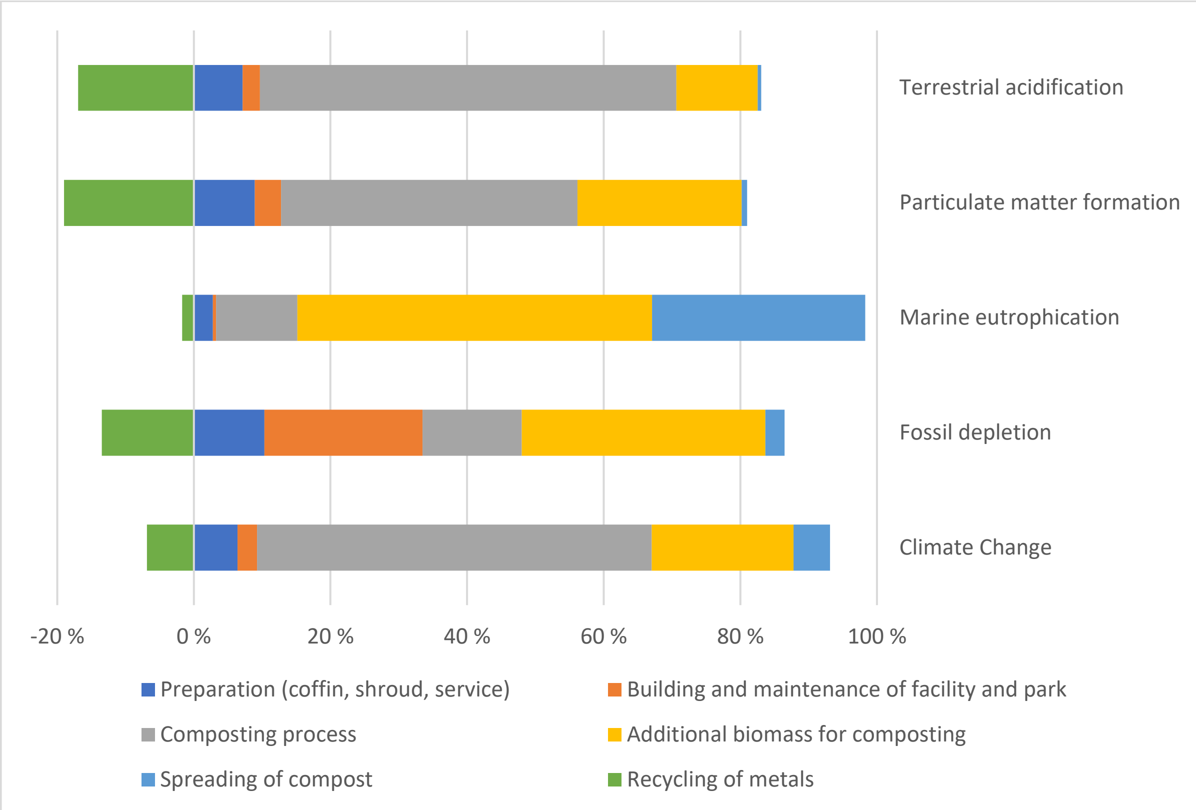


Figure 41: Contribution analysis for the main categories of concern for recomposition

Completeness and consistency

Before the sensitivity analysis is conducted, it is important to be aware of possible incompleteness or inconsistencies. Methods used for this is peer review by group members. Due to time constraints, no other external expert advice has been called upon. In the recomposition system, the most important issues regarding completeness are the lack of data on water use, lack of specifications regarding the composting facility, equipment and park and lack of insight in the destination of the compost. It was therefore hard to determine whether all processes and flows were included. The other systems were judged to be complete in main lines. A table of model improvements is included at the end of this report. Regarding the impact assessment, openLCA has limited functions. For example, it is not possible to retrieve the list of flows without characterisation factors. Also, it is not possible to conduct perturbation analysis. Furthermore, previously discussed issues with water depletion inhibit analysis of this category.

Regarding consistency, the most important issues are variability in data sources, differences in technical level and differences in geographical representativeness. For burial, cremation and resomation, detailed LCA studies were used as a basis. Green burial mostly borrow similar processes from this. In contrast, data for the recomposition system was mainly received from the commissioner.

Recomposition is the only technology still in experimental phase. The other technologies are well documented. This may lead to mainly theoretical and wrong estimations. Most process data was adapted to US geographical characteristics. However, because the research was conducted from the Netherlands by European students, it may be possible that certain cultural characteristics are not reflected in the model design.

11.3.3 Sensitivity analyses

1. *Land use in green burial*

The business model of the natural burial sites in the Netherlands causes the site to be transferred to nature conservation agencies once the graves' capacity is reached. This is expected to be after 20 till 30 years. No information was found on the business models of green burial sites in the US, therefore the same time span as for traditional burial was used (500 years). If the Dutch business model were to be applied in the US, the shadow costs would drastically decrease. Taking an average of 25 years (a factor 20 lower than the 500 years initially assumed), the shadow costs are so much lower that a change in ranking occurs, green burial now having lower shadow costs than recomposition (see Figure 42).

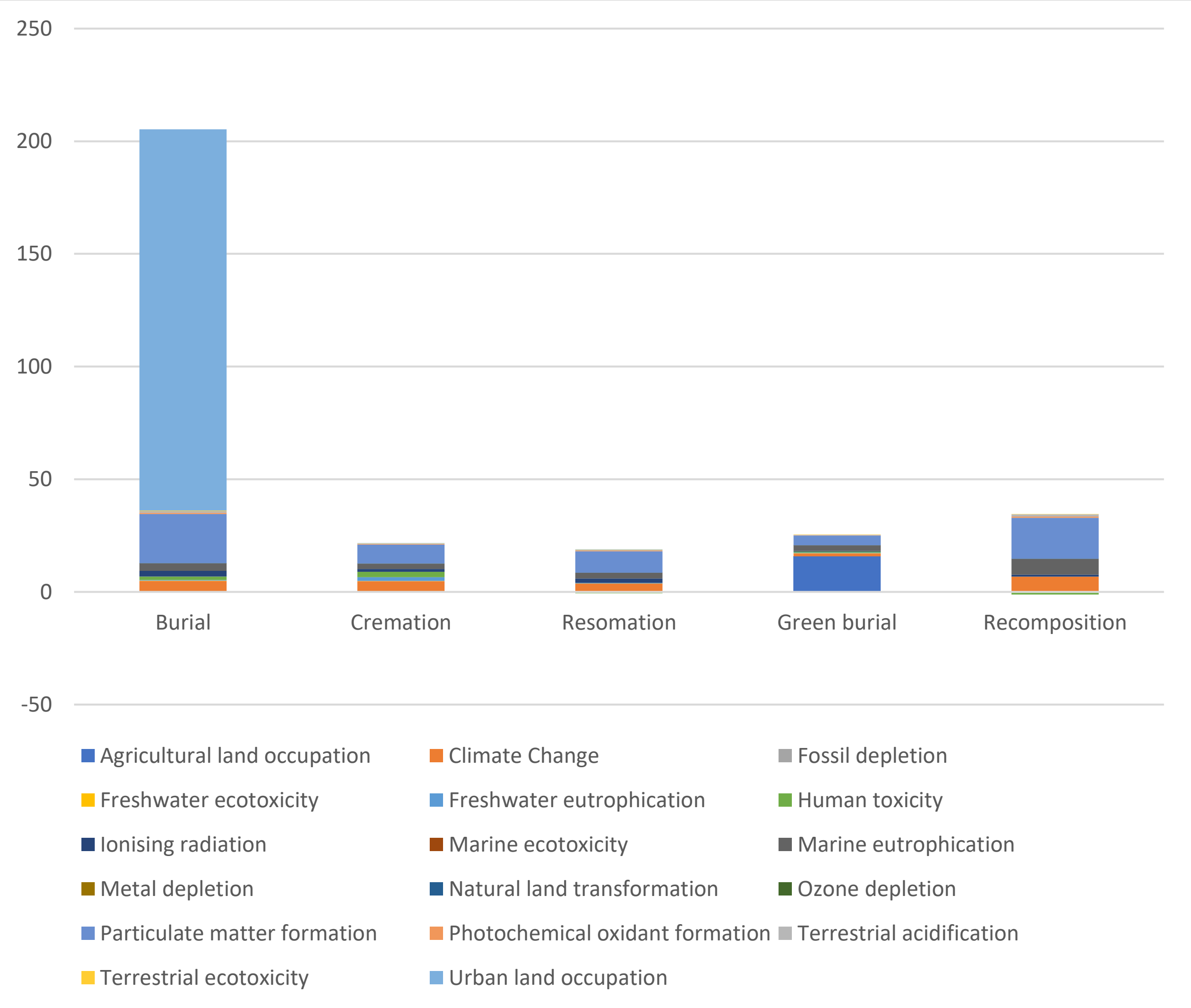


Figure 42: Results of sensitivity analysis 1: Low land use for green burial

This shows that the parameter of land use (in both traditional and green burial) is very important when basing a comparison on shadow costs and should be discussed with parties affected by the outcome of the LCA. When looking at the shadow costs of the alternatives in more detail, green burial seems to have the lowest environmental impact if land occupation is ignored (see Figure 43). With the right business model, it is a very sustainable alternative. However, transport is an issue for green burial, especially of the visitors to the burial site. When taking into account the relatively high impacts from transport of visitors (Keijzer, 2011), green burial might not be such a viable alternative for an urban setting.

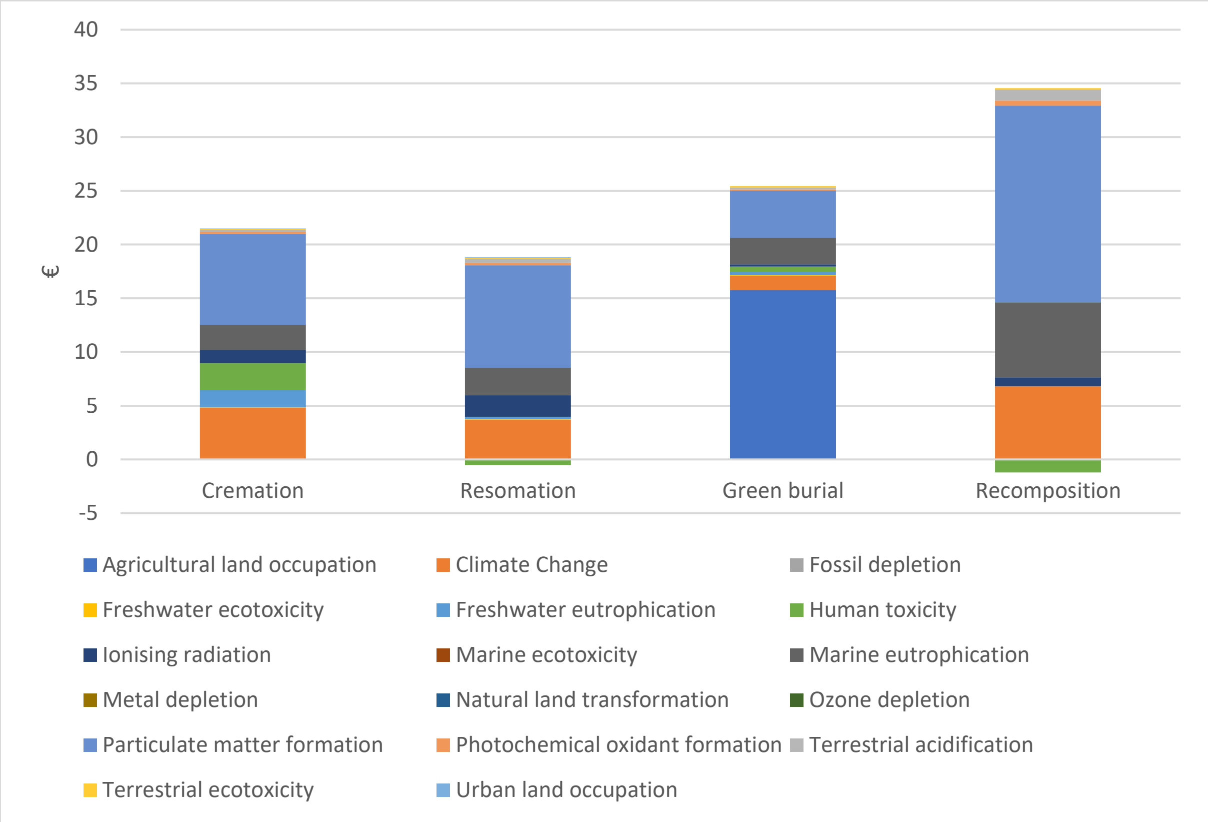


Figure 43: Results of sensitivity analysis 1: Low land use, excluding traditional burial

2. Avoided burden of compost

Besides providing a funeral service, Recomposition provides another service: The composting of organic materials. If this compost can be used normally, it would mean that somewhere else, no compost would have to be produced. This is called the avoided burden. The emissions from composting the additional biomass can then be subtracted from the total system emissions. The emissions from composting the human remains will still be included, since that part of the compost arguably serves a different goal to the relatives of the Recomposed person.

In the baseline system, 1053.9 kg materials is composted in total. With the biomass conversion rate of 0.50, this results in 526.95 kg of composting emissions modelled (as compost, at plant). Since the Recomposed person has an assumed weight of 70 kg (35 kg composting emissions), the avoided composting emissions are 491.95 kg. The results of this sensitivity analysis are presented in Table 17 and Figure 44. The impact categories of highest concern for recomposition are expressed in bold. It can be seen that the avoided burden approach would significantly affect recompositions performance in the categories climate change, particulate matter formation and terrestrial acidification. It is therefore highly recommended to make sure it is legal to put the compost to good use.

Table 17: Results from sensitivity analysis 2: Avoided production of compost

Characterized category indicator results and % change			
	Baseline	**Avoided burden**	**Change**
Agricultural land occupation	0.00	0.00	0%
Climate Change	**272.45**	**106.22**	**-61%**
Fossil depletion	**31.95**	**26.80**	**-16%**
Freshwater ecotoxicity	-0.21	-0.29	-42%
Freshwater eutrophication	0.00	0.00	-156%
Human toxicity	-56.65	-60.23	-6%
Ionising radiation	19.60	13.03	-33%
Marine ecotoxicity	-0.88	-0.97	-10%
Marine eutrophication	**0.56**	**0.50**	**-11%**
Metal depletion	-11.81	-15.66	-33%
Natural land transformation	0.00	0.00	0%
Ozone depletion	0.00	0.00	-21%
Particulate matter formation	**0.36**	**0.13**	**-64%**
Photochemical oxidant formation	0.84	0.49	-42%
Terrestrial acidification	**1.60**	**0.25**	**-84%**
Terrestrial ecotoxicity	0.08	0.08	-1%
Urban land occupation	0.00	0.00	0%
Water depletion	246.02	80.54	-67%

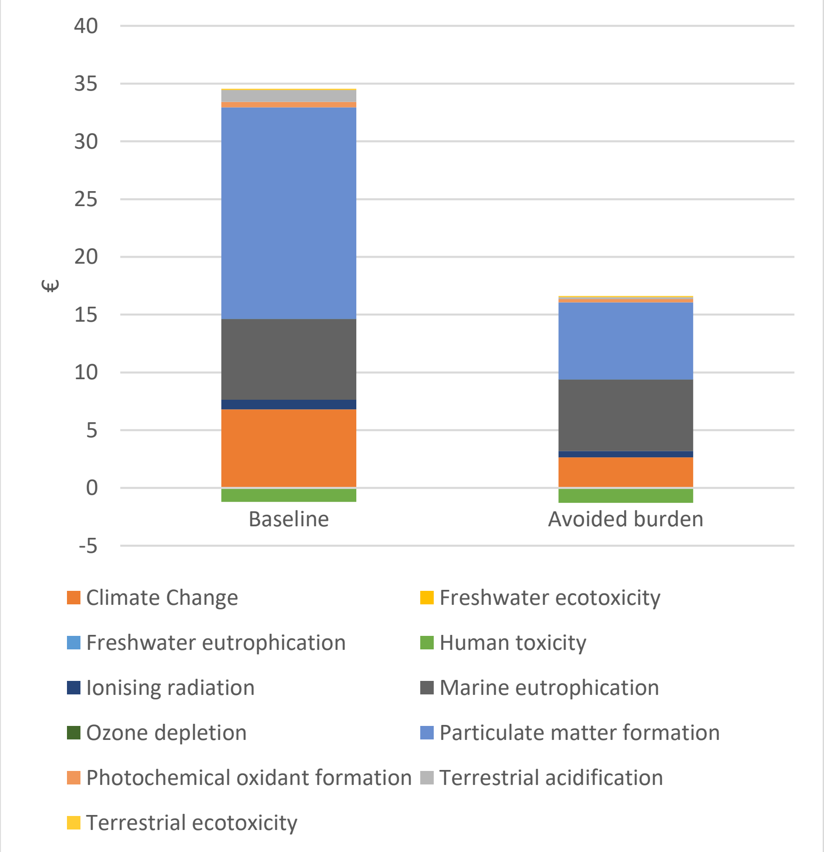


Figure 44: Results in shadow costs from sensitivity analysis 2: Avoided production of compost

With the avoided burden approach, the ranking of the environmental performance among the non-burial technologies shifts (see Figure 45). Where both cremation and resomation had lower shadow costs than recomposition originally, it now has the lowest shadow cost of all alternatives. This shows the potential of recomposition to be a sustainable alternative if it is perceived as a multi-functional process, producing compost as well as a funeral service.

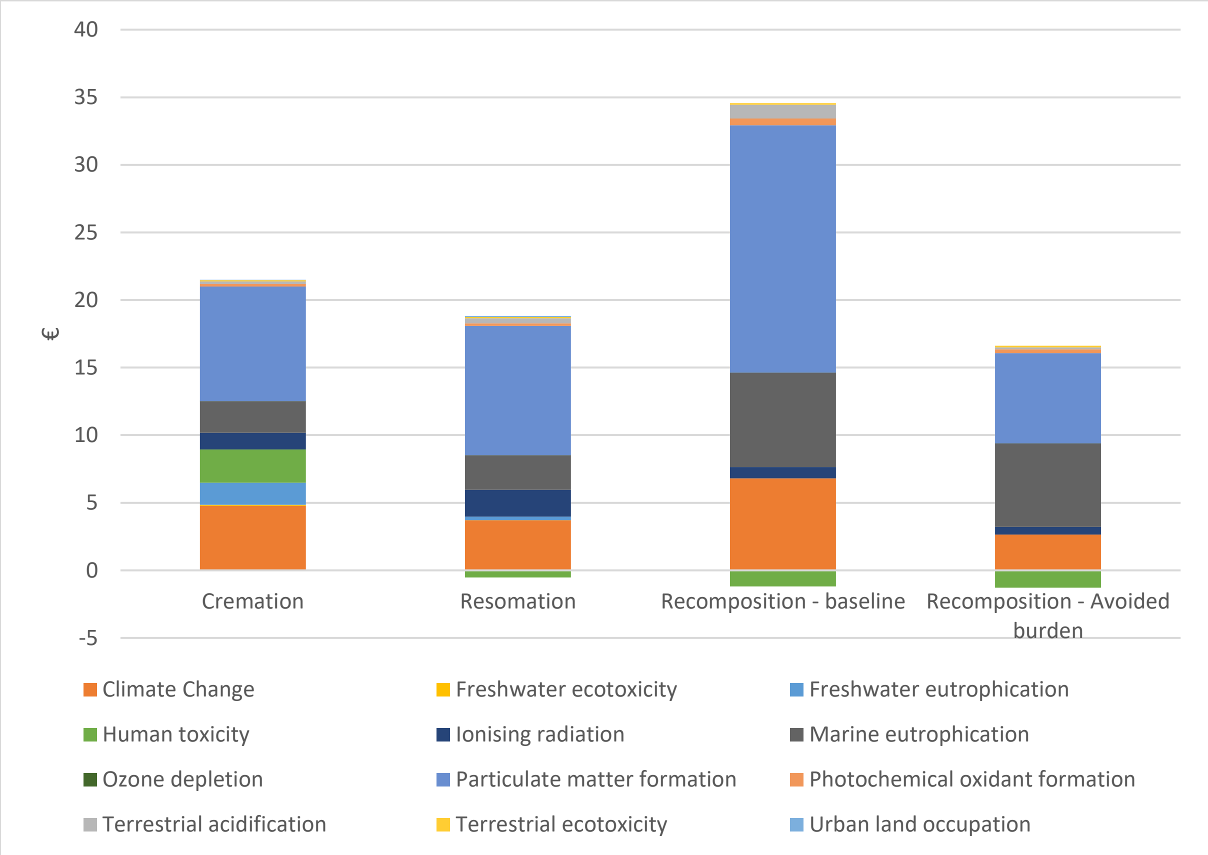


Figure 45: Comparison of funeral alternatives using shadow prices, including both baseline and avoided burden results

3. Different material inputs in composting process

Given the high environmental impact of the additional biomass production, a scenario analysis is done on the inputs of wood chips (using the ecoinvent record *wood chips, softwood, from industry, u=40%, at plant* as a proxy) and alfalfa mix (using *hay extensive, at farm* as a proxy). For both wood chips and alfalfa mix, 4 alternatives are selected (see appendix E.3 for a description of these processes). Each scenario has one changed parameter and one baseline parameter. For example, in the scenario where hay from intensive organic agriculture is used as an input, the wood chips from the baseline scenario are used. Conversely, in the scenario where waste wood chips from industry are used, the alfalfa proxy from the baseline scenario is used. Using this method, it can be seen whether changing either the current wood chips or alfalfa mix proxy would result in better performance. The normalized results are presented in Figure 46. Impact categories with a zero value (because of lacking characterization results or lacking normalization values) have been omitted.

Overall, the baseline scenario is the most sustainable option. Minor gains can be made by switching between wood chips inputs, but each of the options also has minor losses. Switching to a different alfalfa proxy always results in (much) higher environmental impacts. That brings to question whether the actual impacts of the alfalfa mix are higher than the baseline scenario makes believe.

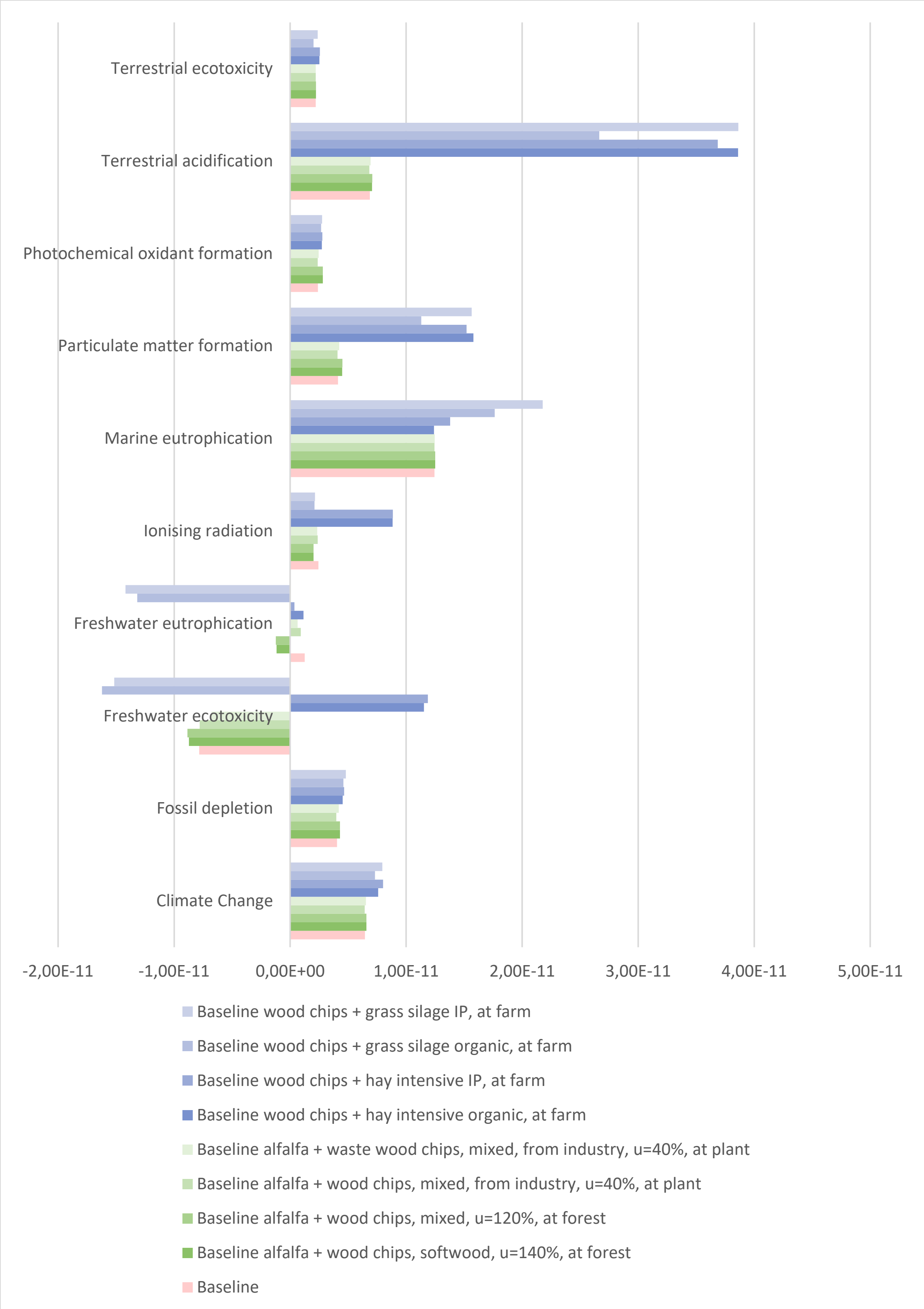


Figure 46: Normalized results from scenario analysis using different additional biomass input (reference: World, 2000).

The results are also presented in the form of shadow costs (see Figure 47). The same conclusions can be drawn. The type of input used for alfalfa mix is a very important factor in the total system sustainability. If the recomposition process could make use of some kind of waste for this part of the biomass, the sustainability of the system could be increased drastically. Perhaps urban biomass from garden or park clippings or other organic waste could (partially) replace the need for alfalfa mix.

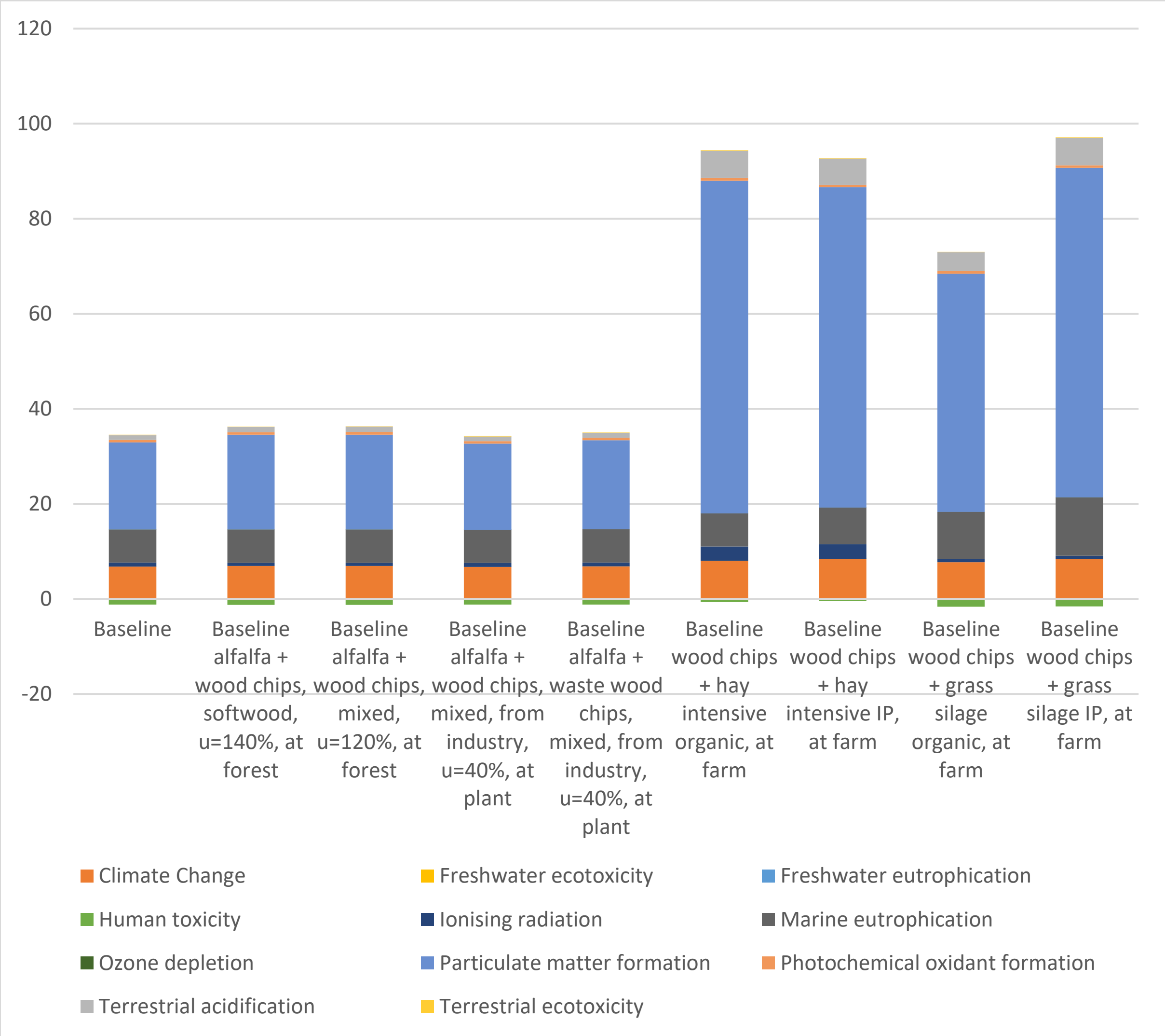


Figure 47: Results in shadow costs from scenario analysis using different additional biomass input

4. ReCiPe Endpoint (H) instead of shadow costs

The final sensitivity analysis concerns using the endpoint method from ReCiPe to interpret the results. That method categorises impacts in damage to ecosystems (expressed in loss of species*year), damage to human health (expressed in disability adjusted life years, or DALY) and resource depletion (in $). It assigns priority to some impact categories over others and therefore includes a weighting step. The results are presented in Figure 48 to Figure 51.

Similarly to the shadow cost method, land use dominates the environmental impact on ecosystems. From the categories other than land use, climate change clearly receives a heavy weight in this method. The ranking of the alternatives under study does not change.

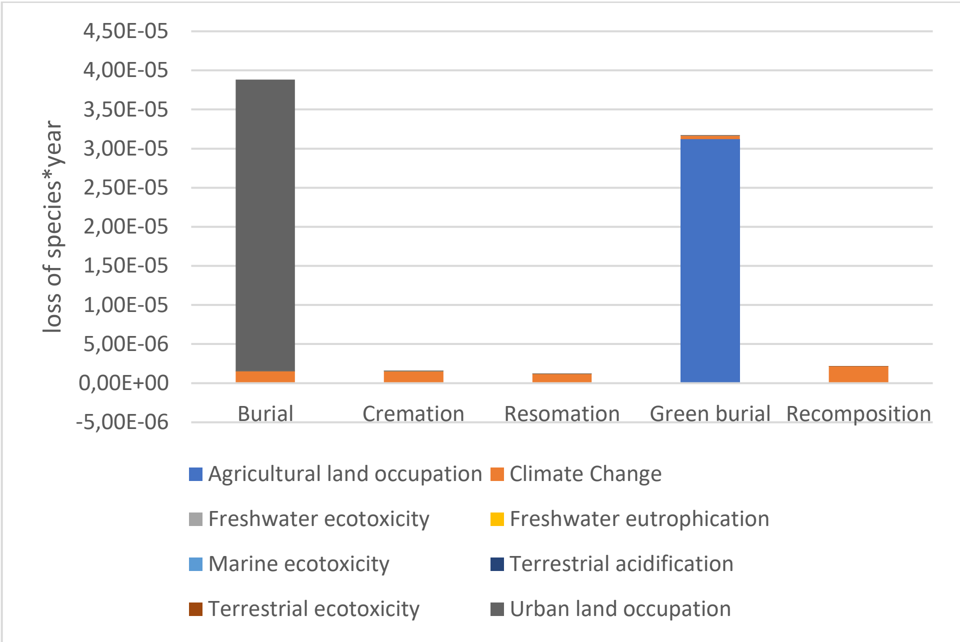


Figure 48: Results using ReCiPe Endpoint (H): Ecosystems impact categories

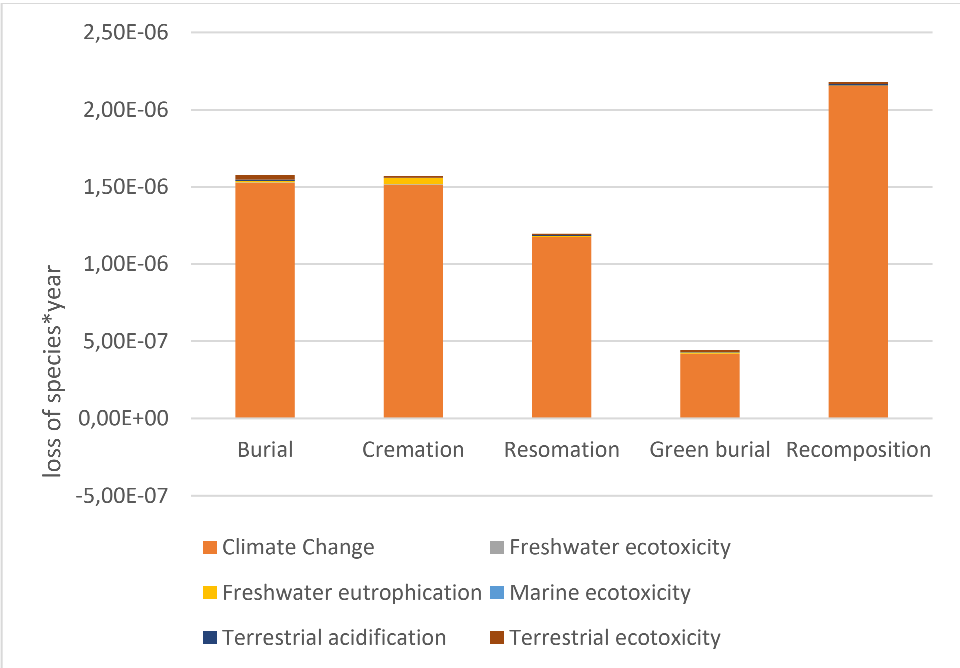


Figure 49: Results using ReCiPe Endpoint (H): Ecosystems impact categories excluding land occupation.

This method does assign the highest impact to recomposition in the area of human health. Again, this is mainly because of the heavy weight assigned to climate change. Seeing recomposition as a multi-functional process and thereby allocating part of the composting emissions to the production of compost would hugely improve its ReCiPe Endpoint score for damage to human health.

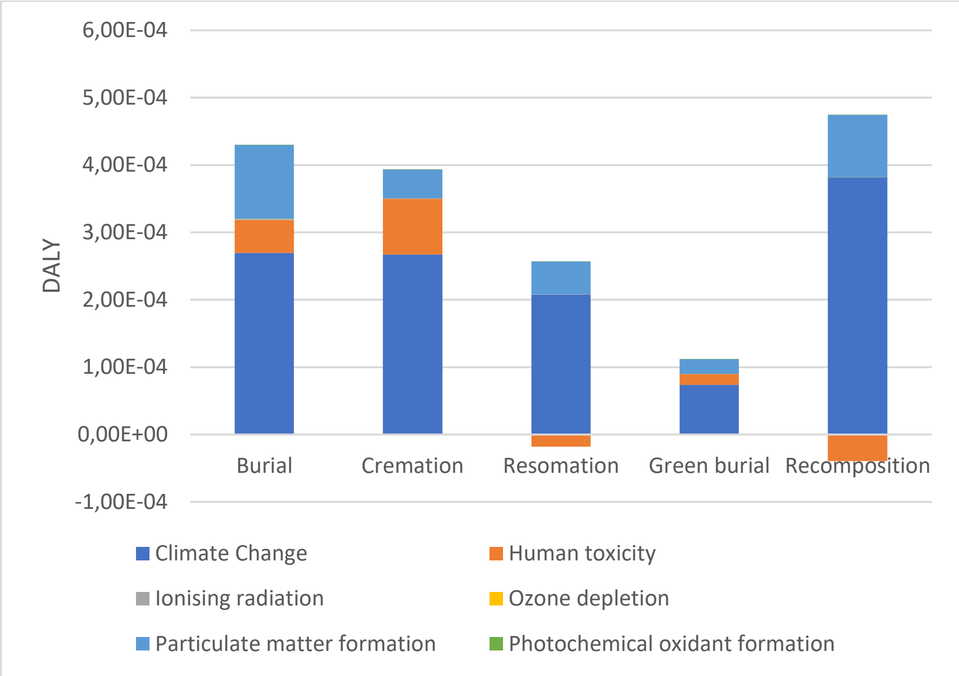


Figure 50: Results using ReCiPe Endpoint (H): Human health impact categories.

Finally, recomposition performs reasonably well regarding resource depletion. Metal depletion, an impact category that recomposition performs second best in after resomation, only compensates a little for the total scores. This implies that this method assigns a relatively heavy weight to fossil fuel depletion.

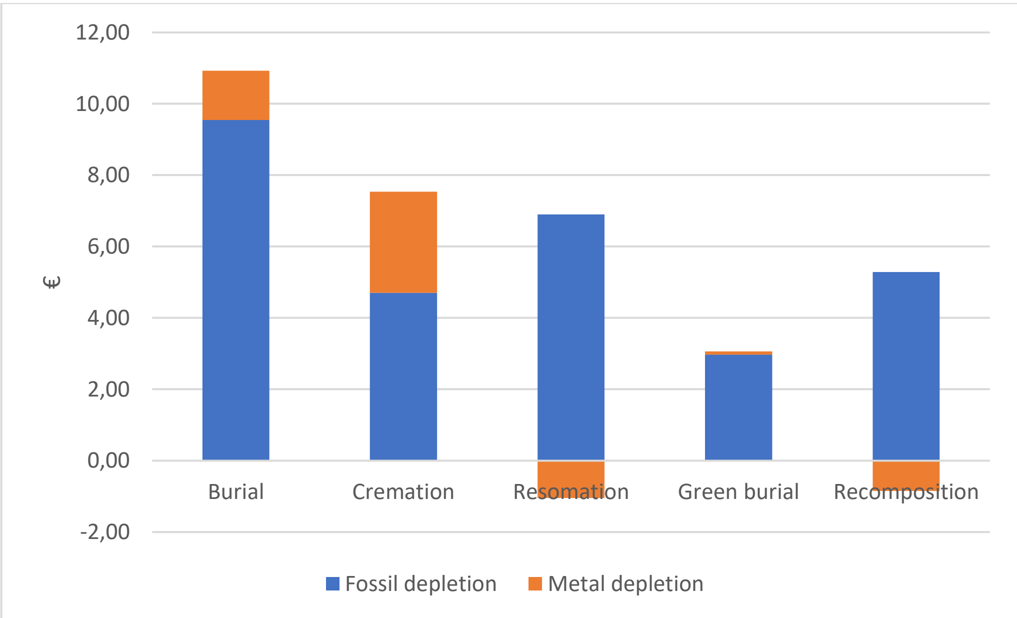


Figure 51: Results using ReCipE Endpoint (H): Resource depletion impact categories.

Overall, by dividing the impact in these three main areas, the ReCipE method provides a little more detail than the shadow prices method. The two methods are most valuable when used simultaneously.

5. Shadow costs scenario analysis

The report on land use made a distinction between three different scenarios. With the knowledge of the shadow prices of each individual funeral alternative obtained in this chapter, the total shadow prices for all three scenarios can be calculated. A comparison between the three total shadow prices would identify which of the three scenarios would require the lowest financial compensation for their environmental impacts (see Table 18).

The complete calculations can be found in appendix E.5, but an overview is provided below.

Table 18: Total shadow prices of the three scenarios

Scenario	Total shadow price
Scenario 1: The Lock in	625,596 USD
Scenario 2: The New Green Movement	781,685 USD
Scenario 3: The Paradigm Shift	448,741 USD

One intriguing conclusion that can be drawn is the poor score of the new green movement. As optimistic as the scenario may sound, having a relative high share of green burial requires a large financial compensation for the change in land use.

On a more positive note for the UDP, the scenario with the highest share of recomposition also has the lowest shadow price. Although it should be mentioned that theoretically a lower shadow price can be achieved by adding more cremation and resomation.

11.4 Discussion and conclusion

The aim of this part of the report was to (1) provide insight in the main environmental issues related to different funeral technologies on the US market, (2) to provide insight in the main environmental hot spots of recomposition and (3) to compare the environmental performance among alternatives. Another aim was to (4) deliver a detailed and flexible LCA model, in openLCA, to the commissioner that enables relatively easy yet complex LCA study of the funeral methods (especially recomposition) in the future.

The analysis of normalized results shows that the main environmental issues of the funeral industry in the US market are related to urban land occupation, marine ecotoxicity, human toxicity, freshwater eutrophication, freshwater ecotoxicity and agricultural land occupation. The most serious impacts are urban land occupation from traditional burial and freshwater eutrophication for cremation, from the scattering of ashes. Given the fact that these technologies are and will probably remain the dominant ones, it is important to improve these technologies in those areas. A positive message for the Urban Death Project is that recomposition seems to outperform the other technologies in each of the impact categories of greatest concern for the funeral industry. This means that when looking at the funeral industry as a whole, the main environmental impacts are caused by the other funeral technologies. In order to make the (inter)national funeral sector more sustainable, it seems best to either increase the market share of the lesser impactful technologies (recomposition and resomation in particular, and principles from green burial) or improve the environmental performance of the other technologies (especially burial and cremation).

However, using the weighting methods of shadow prices and ReCiPe Endpoint (H), recomposition seems to perform less well. In most cases, recomposition ranks in the middle of the alternatives. Especially its relatively high contribution to particulate matter formation, marine eutrophication and climate change causes it to be outranked by resomation and often cremation and green burial as well. Besides these, fossil depletion and terrestrial acidification are also categories of concern.

The main contributing stages in the recomposition process are the composting process and the production of additional biomass. During composting, emissions of methane, dinitrogen monoxide, ammonia and nitrogen oxides cause the main impacts. Reducing the emissions of any of those would improve the performance of the system. Reducing ammonia emissions would especially influence particulate matter formation and terrestrial acidification. Reducing methane and dinitrogen oxide would reduce impact on climate change.

The production of alfalfa mix (using extensively farmed hay as a proxy in this model) is the main cause of the high impact of the biomass production stage. The recomposition process needs around 1000 kg of additional biomass for each body. The sheer volume of biomass produced causes this stage to have an environmental impact that is hard to mitigate. Even more, the proxy used for alfalfa mix in this study seems to be on the optimistic side of the spectrum, with relatively low associated impacts. It is likely that real-world production has higher associated impacts.

To reduce the impact on fossil depletion, non-fossil memorial park maintenance equipment should be considered. To reduce the impact on marine eutrophication, the runoff of excess nitrogen from the compost should be managed. It might be a good idea to look into ways to apply the compost in ways where nitrogen is used as efficiently as possible. Finally, it is worthwhile to look into more sustainable alternatives than the conventional cotton shroud.

Land use is a very important parameter in this LCA. Since, in the US, a burial provides an 'eternal' resting place, the environmental impacts associated with land occupation and graveyard maintenance are in theory infinite. This causes both traditional and green burial to perform very poorly. However, the business model of the natural burial sites in the Netherlands causes the site to be transferred to nature conservation agencies once the graves capacity is reached. This is expected to be after 20 to 30 years, depending on site characteristics. If this business model is applied in the US, green burial is suddenly a very sustainable option. Transport is an issue for green burial, especially cumulative burdens from visitors to the funeral, but this can also be the case for other funeral technologies, depending on where relatives live.

This brings up another point for discussion. Keijzer (Keijzer, 2011) found that surrounding activities such as correspondence, flower cultivation, food and beverage production and visitor transport make up 75-95% of the total environmental impacts of a funeral. Taking into account the relatively high impacts from transport of visitors, green burial might not be such a viable alternative for an urban setting. Furthermore, Keijzer (2011; 2016) found that the environmental impacts of dying are quite small compared to other activities during a person's life.

A similar discussion can be held regarding recomposition. Given the high need for biomass that is grown in an agricultural setting, it can be debated whether recomposition is the perfect 'urban' solution to environmental problems of deathcare. Cultivating 1000 kg of biomass outside of the city and transporting it into the city for every recomposition seems not very scalable. Even more, 500 kg of compost is produced in the process. If people do not take that home (because they only want a little or because they do not have a garden) or cannot be applied in urban areas (e.g. for legal or public perception reasons), it as to be transported out of the city again. This is a serious point of concern for recomposition and has to considered in the further development of the technology and its business model.

Recomposition is different from the other funeral methods in that it provides more than one function. Where the other processes are designed to safely dispose of one human body and produce nothing but wastes or emissions alongside, recomposition also produces around 500 kg of compost. The process uses around a ton of additional biomass (currently wood chips and alfalfa mix) to recompose one average 70 kg human body. This immediately touches upon one of the two largest contributors to recomposition's environmental impact. The first are the emissions related to the composting process itself. In the composting process, microorganisms release a large amount of gases. Among the most problematic are methane, ammonia, nitrogen oxides and dinitrogen monoxide. These gases contribute to climate change, particulate matter, acidification and marine eutrophication. In these areas, recomposition performs worse than most of it competitors. Especially particulate matter formation can be seen as a problem in an urban context. Furthermore, the cultivation of this amount of biomass, assumed to take place outside of the city, has high associated environmental impacts. Depending on the type of cultivation (organic, intensive, or extensive), the types of impact differ but range from agricultural land use, water use, overfertilization, pesticide use and to a lesser extent its transport into the city. It is very important to the environmental performance of the recomposition system to choose a sustainable source.

Ideally, waste biomass from the municipality of Seattle is used in the process, killing two birds with one stone. Recomposition then becomes a multi-functional process: Upcycling municipal biowaste, producing compost (therefore also avoiding production of compost in another facility) and of course respectfully providing a last resting place for a person. It might seem crude and technical to look at it this way, but it is actually a holistic view. A sustainable world is organized in networks, just like nature. It is full with symbioses and interconnections to make optimal use of energy and resources. By looking at the recomposition process as a multi-functional one, the environmental impacts can be attributed to the various functions. Recomposition has relatively high impacts due to the sheer quantity of biomass used and the emissions produced in the composting process. However, considering recomposition as a multi-functional system reveals a sustainable picture.

One last note should be made about the relative importance of these findings. Keijzer (2011; 2016) found that the environmental impacts of dying are quite small compared to other activities during a person's life. This also influences the relative performance of the burial alternative. If the system boundary is set wider (for example by including visitors and other auxiliary processes), the relative differences between the alternatives will quickly become smaller. Nonetheless, there is a lot of room for improvement in the current funeral industry and some practices (unnecessarily) cause substantial damage to the environment. It is important to be aware of these areas of greatest concern in an early stage of system design.

11.5 Points for improvement and recommendations for further research

Some mistakes have been identified in the LCA. These regard the values of some parameters, assumptions and the design of the model. However, because a large part of the analyses was already done and because the economic part of the report uses these same analyses results, it is decided not to adapt these but to mention the points for improvement in Table 19. It is expected that these do not have a significant influence on the final results, since the core parameters are well established. Also in Table 19, the main points for improvement in parameter and model design are mentioned. This table can serve as a starting point for the commissioner to keep on improving the LCA model and use it for future analyses. Furthermore, a few sensitivity analyses is proposed.

Table 19: Main points for improvement of this LCA study

Parameters	
Maintenance of the graveyard/green burial site	The period of maintenance assumed for the two differs. In the burial system, this is put at 100. In the green burial system at 500. This should be made consistent. See ‘calculations’ in the green burial system for a discussion on the topic.

Water use for recomposition	This has been excluded due to limited time but could quite easily be included.
Electricity use for recomposition stages	This now is derived from Hottle (Hottle, 2017), who admitted these were rough estimations. Extra electricity use for transporting the additional biomass has been included (see calculations of recomposition system). The *compost, at plant* process from ecoinvent also includes electricity for mixing and aeration. This should be looked into in more detail.
Uncertainty data	Overall more uncertainty parameters could be included. For example, Keijzer (Keijzer, 2016) discusses the quantity of natural gas use in the cremation system, which varies substantially. Including uncertainty parameters and subsequently carrying out an uncertainty analysis could improve robustness of the results.
Emissions from embalming fluid	The production of embalming fluid has been included, but the emissions from either burying or burning it are not included. Formaldehyde-containing embalming fluids are known to have toxicity impacts, so should preferably be included.
Transport data	Transport data for scattering of ashes were taken from Keijzer & Kok (Keijzer & Kok, 2014). Since Seattle lies on the coast, the values from the Dutch study were assumed to be representative. However, for all systems, transport distances rely on very rough assumptions (described in the calculation sections of the different systems).
Emissions in burial	Due to the burial vault, it is reasonable that decay and emissions are very different than what is modelled here (landfill model). This could be improved in future study.
Scattering of ashes	Data for scattering of ashes over land were adapted from Keijzer et al. (2014). This is all scattering on scattering fields, which is not realistic. Therefore the grass seed, petrol etc. may be overestimated. The transport does reflect scattering anywhere.
Disposal of display coffin	Modelled as disposal, *building, door, inner, wood, to final disposal.* Is currently wrongfully set at 0.2533 m2. Due to time constraints, no new calculations have been made.
Emissions from the body during recomposition	The emissions currently modeled assume the bones to be removed from during composting. If the bones are also composted, the emissions can be assumed to be the same as in the burial systems. This can be adapted in future LCA.
Model design	
Urn for 1 month storage	In the Keijzer & Kok (Keijzer & Kok, 2014) LCA, a PVC urn is included for the (mandatory) storage of the ashes for one month. First, the question is whether this happens in the US
Proposed sensitivity analyses	
Coffin use	Display coffin assumed in recomposition, this might not be the case
Shroud	Shroud can be made from a different material, e.g. linen or hemp
Avoided burden of fertilizer	N content of mortality compost: 1.5%. P content 0.5% (Rozeboom & Ross, 2014). Seeing as we have 526.95 kg compost, this means there is 7.90 kg N and 2.63 kg P in there. This can be the starting point for avoided burdens of fertilizer use.

This study mainly used data from the Netherlands (adapted to US data as much as possible) and was conducted by European students. Deathcare differs quite a lot per region and therefore, researchers more aware of US culture and society should look whether the model design reflects reality well enough. Furthermore, recomposition is a very young technology. The LCA should be conducted again once every while with updated model design and process data for the recomposition system. It would be interesting to expand the system of this LCA to include all auxiliary processes (like visitors and their transport) of a funeral in Seattle to gain insight in the relative share of the funeral technology itself in the whole funeral. Also, with reference data of an average US citizen and the total environmental impacts of the funeral, to get more insight in the relative importance of these findings.

Chapter 12 References

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