KWR 2020.121 | October 2020

Organic kitchen waste through the sewage system: an environmental, legal and governance aspects analysis

KWR

Bridging Science to Practice

Partners

Report

Organic kitchen waste through the sewerage: an environment and governance analysis

KWR 2020.121 | August 2020

Order Number
402685

Project Manager
Petra Holzhaus

Client
Collaboration Region Samenwerking Afvalwaterketen Flevoland – SAF, Leidschendam- Voorburg Municipality, Dunea, Stichting PIT, TVVL, Techniek Nederland (previously Uneto-VNI), Emerson (InSinkerator)

Authors
Tessa van den Brand en Nicolien van Aalderen

Quality Assurers
Prof. Dr. K. van Leeuwen, Dr. Ir. C.H.M. Hofman-Caris

Submitted to

This report is not public and is only provided to the clients of the advisory project. KWR will refrain from distributing this report and will therefore not provide it to third parties, unless the parties agree otherwise. The client is entitled to distribute the report provided that KWR has given prior permission for this. KWR may attach conditions to the permission for the distribution of (parts of) the report.
Methods, calculation models, techniques, designs of test installations, prototypes and proposals and ideas made by KWR as well as instruments, including software, which are included in the research result are and will remain the property of KWR. All rights arising from intellectual and industrial property, as well as copyrights, also remain with KWR and therefore remain the property of KWR.

Keywords
LCA, food scraps, governance

Year of publication
2020

More information
Ph.D. M.Sc. Tessa van den Brand
T 0306069629
E Tessa.van.den.Brand@kwrwater.nl

PO Box 1072
3430 BB Nieuwegein
The Netherlands

T +31 (0)30 60 69 511
F +31 (0)30 60 61 165
E info@kwrwater.nl I
www.kwrwater.nl

October 2020 ©
All rights reserved to KWR. No part of this publication may - without prior written permission from KWR - be reproduced, stored in an automated database, or made public, in any form or in any way, be it electronic, mechanical, by photocopying, recording or any other way.

Summary

In this study, the impact on the environment and the legal and governance aspects of disposing organic kitchen waste through the sewerage are studied. This is an addition to the technical analysis reported in 'Assessing the impact of food waste disposers on the indoor sewerage system' KWR 2020.079.

In determining the environmental impact, the focus was mainly on the question: which 'levers' can be pulled to get more out of this concept. For this, a comparison has been made of three scenarios: disposal of organic food residues via organic waste container (organic scenario), disposal via the residual waste (residual waste scenario) or disposal in which the food residues are discharged through the sewerage via a food waste disposer (sewerage scenario). The STOWA 2015-07 report serves as the basis for this study. It is assumed that the inventory of how much material, energy, chemicals, etc., has not changed, but this model has been updated with the help of a new life cycle inventory (LCI) database and a revised impact assessment method. As a result, the new results deviate significantly from the results in the STOWA report. The conclusion that the removal of organic kitchen waste via organic (VGF) waste has a lower impact than via the sewerage system, however, is also confirmed with this new model (with accompanying assumptions), although the difference is smaller. The parameter sensitivity analysis shows four important key points. Firstly, the use of a greener form of energy in the process appears to have a particularly favourable effect on the scenario with discharge via the sewerage system. Secondly, reducing the water consumption in the sewerage scenario from 16.8 to 10L appears to reduce the environmental impact by ~5%. Thirdly, it follows from this study that in the scenario with discharge via the sewerage, the impact of the grinder is very large. Since the impact is calculated per kg of food residues, the impact of the grinder decreases if more food residues can be ground with it. It turns out to be worthwhile (~20%) if several households were to dispose of their kitchen waste via the same grinder. Finally, the quality of compost appears to be of great importance for the comparison with the organic scenario. The research by Bolzanella et al., 2003 shows that the quality of the compost can vary greatly, and this distribution means that at best the impact of the organic scenario is about 35% lower than with an average compost quality. This obviously has a major influence on the mutual comparison of the different scenarios. The advice now is to focus primarily on extending the life of the grinder. The disposal of food waste is mainly considered in high-rise buildings, where food waste is mainly disposed of via residual waste. In this model, the removal of food residues via the sewerage system scores significantly better than the removal via residual waste.

Implementation of food waste disposers in homes

An important obstacle to the disposal of organic kitchen waste via a waste disposer is the current ban on its use, as included in the national waste policy. The starting point of Dutch waste policy is currently 'sorting at the source'. Due to this segregated collection, various waste streams can be efficiently recycled. Within this approach, many municipalities in the Netherlands therefore collect organic waste as loose residual flow from households. Food waste disposers are considered undesirable by the Ministry of Housing, Spatial Planning and the Environment because they place an additional burden on the sewerage system. This is because the effluent could possibly lead to more blockages and because the processing of the effluent at WWTPs produces more emissions. Reference is also often made to the aforementioned LCA by STOWA, which has shown that separate collection of organic waste is the most efficient way to collect this waste stream.

However, the local conditions for waste collection can differ greatly from the national average. For example, not all municipalities collect household organic waste, and its collection appears to be more difficult for high-rise buildings.

The use of waste disposers therefore seems most promising for households to which these conditions apply. Reflecting on current legislation, it seems possible to use disposers in some cases. For example, municipalities are free to introduce alternative ways of waste collection for certain areas. When this is used for disposers, this also

means that the wastewater must be processed separately, outside the WWTP. The successful implementation of a pilot currently appears to be the most promising method for realising changes in current policy. Being able to demonstrate that the enriched waste stream from the disposer does not place an additional burden on the WWTP is a central element in this.

Table of contents

1 Introduction

There are several options for removing organic kitchen waste: one of them is through the sewerage. A food waste disposer is a kitchen appliance intended for the processing of organic kitchen waste and installed under the sink. Most of the food waste is reduced to small particles (<5 mm) and goes to the sewage system via the kitchen sink (Marashlian and El-Fadel 2005). The effect of adding (ground) food residues to wastewater on sewage treatment plants has not yet been sufficiently investigated (Zan et al. 2018). The separate collection of kitchen waste (GFT scenario) comes with high transport costs. Hence, combined transport with domestic toilet wastewater, with increased biogas production, could both reduce financial costs and have a positive impact on the environment (Maalouf and El-Fadel 2017). Unlike composting, nutrients are recovered, energy consumption is reduced, and greenhouse gas emissions can be minimised (Yang et al. 2010). The use of food waste disposers is a promising approach to separate and collect household food waste, especially in apartment buildings where the waste separation rate is low. The feasibility of the application has not yet been sufficiently investigated in width. In this report we investigate the environmental effects (chapter 2) of these food waste disposers.

The second part of this report (chapter 3) focuses on the legal frameworks for the introduction of food waste disposers. First, the basic principles for waste sorting in the Netherlands will be explained, including the link between waste sorting and the realisation of a circular economy. After that, the status of the current organic waste collection will be examined and the ban on FWDs will be zoomed in on. After a brief background of the ban, section 3.3 will outline the current considerations for its enforcement. This chapter ends with an overview of the most important considerations for current policy and options for adapting it. Section 3.4 will discuss the division of responsibilities and costs and benefits associated with the use of FWDs. Finally, a few example projects are included in the concluding section 3.5.

2 Environmental impact

2.1 Introduction to environmental impact

Awareness of sustainability is growing within society. It is therefore increasingly important to include this in the further development of technologies and concepts. In fact, sustainability is often the driving force behind new concepts. However, the term 'sustainability' encompasses more than just the effect on the environment: it is also relevant whether there are other advantages or disadvantages such as economic and social aspects (comfort). Within this study we only look at the effect on the environment; We do this by performing a life cycle assessment (LCA) analysis.
When starting an LCA analysis, it is important to first determine the goal and scope (Figure 1); the choice of the functional unit is particularly relevant here. We will revisit this later. In an LCA analysis, the cradle-to-grave method is used to determine the environmental impact, taking into account the entire life cycle, from the extraction of the raw materials to use and waste disposal. In this process information is collected about the consumption of energy, materials and chemicals, transport, emission of substances and many other things. This is part of the 'inventory analysis' as shown in figure 1. It is possible to use life cycle inventory (LCI) databases, which provide information about what is cradle-to-grave involves products and processes. Then an impact assessment is evaluated: this is actually the impact assessment, which gives scores on environmental indicators. The life cycle impact assessment (LCIA) data are used for this. The arrows in figure 1 indicate that there is a continuous interaction; it is an iterative process. This results in an improvement of the analysis, as it contributes to the breadth and consistency of the analysis.

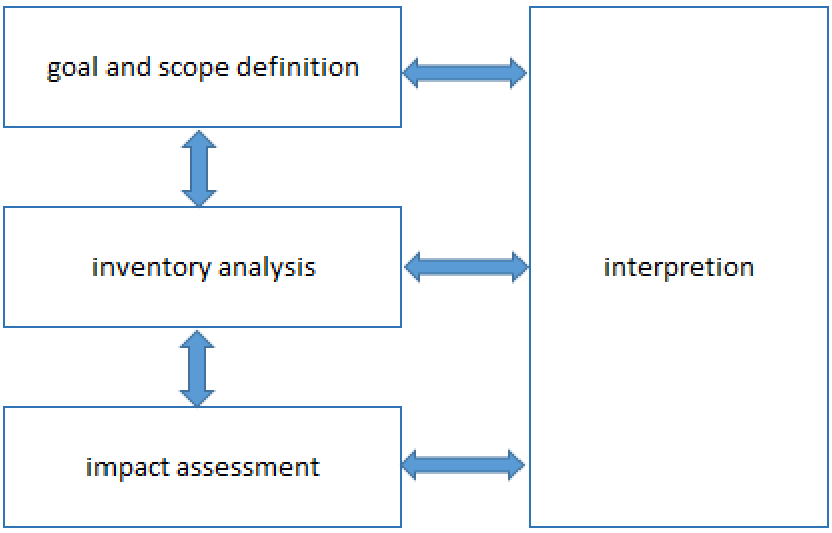


Figure 1 Schematic representation of the LCA analysis

In this study we use the EcoInvent database, and Recipe as our impact assessment method. Recipe uses seventeen to twenty-two midpoint impact categories, each of which represents a separate environmental problem. These are then translated into where the environmental damage occurs, the so-called endpoints (Figure 2). Three endpoints have been defined: public health (human health), ecosystems and raw materials. This gives the opportunity to combine different environmental effects. This increases the uncertainty of the analysis (the results are 'translated'), but it usually makes the interpretation a lot easier. It is therefore desirable to describe both results, both midpoints and endpoints. One midpoint (climate change) has an effect on both endpoint human health and ecosystems, see Figure 2.
The impact can be expressed in different ways. A commonly used method is in CO_2 equivalents, where the impact is calculated in kg CO_2 per functional unit. A disadvantage of this method is that other effects, such as land use or toxicity, are not taken into account. Another method is the use of ecopoints, whereby such effects

are taken into account and scaled. In this way, all effects are added together, taking as a benchmark that one average Western European person per year causes an impact of 1000 ecopoints (Baayen H., 2000).

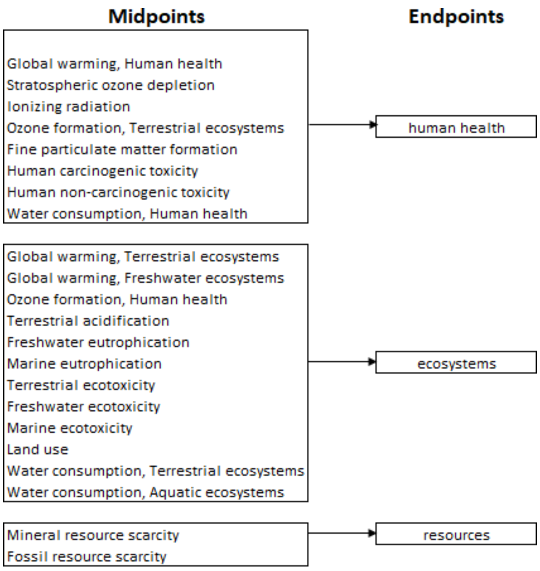


Figure 2 overview of midpoints and endpoints in the recipe method

There are various reasons for carrying out a life cycle assessment (LCA) analysis on a regular basis. New insights regularly emerge about a technology, or developments within that technology. As a result of this, for example, the consumption of energy or chemicals can (strongly) change. Moreover, this information can give you a new direction for further research. Another reason for the desire to regularly review LCA is that data in used life cycle inventory (LCI) databases (EcoInvent for example) will be improved or that the evaluation will be revised through a revision of the LCIA method. Moreover, the outcome of the Recipe method is defined in such a way that 1,000 ecopoints correspond to the impact of an average Western person per year (https://www.pre-sustainability.com/download/EI99_Manual.pdf). As a result, the 'value' of 1 ecopoint can change over time, and you cannot compare recent data one to one with old data.

2.2 Material and methods

According to the ISO standard (14040 and 14044) it is important to accurately include various matters in a report. These matters relate to: description of goal and scope, data inventory analysis, impact assessment and interpretation of the results. Below is the information on how this model is constructed for the study reported here.

2.2.1 Goal and scope

The purpose of this analysis is to update the environmental impact of various scenarios for the disposal of vegetable and fruit waste. Food residues are usually disposed of via a organic waste container (organic scenario). However, in the case of high-rise buildings (flats, etc.), this often happens via the residual waste container (Residual waste scenario). Disposal of food residues via the sewerage, with the intervention of a disposer, is a future possibility (sewerage scenario). These three scenarios are evaluated in this study. This is done on the basis of three sub-processes: 1) disposal: how food residues are disposed of, 2) processing: what additional costs are incurred for processing the added food residues (e.g., energy, additives, emissions) and 3) application: the possible formation of substances and / or energy that can be recovered elsewhere. Table 1 provides a brief summary of the scenarios; a detailed description can be found in the STOWA report 2015-07. For the residual waste scenario additional use was made of MerLAP 2002 for the data inventory. A revision of the LCA study was necessary because the previous study used outdated processes and impact calculation methods. Moreover, we would like to provide insight into which factors largely determine the environmental impact (or which levers we might be able to pull), in order to estimate future prospects.

Table 1 Brief overview of the scenarios.

	Scenario		
Sub-process	Organic	Residual waste	Sewerage
Disposal	Transport of container by truck	Transport of container by truck	Transport via disposer and sewerage (pump energy)
Processing	Processing by means of fermentation and extra biogas production, which reduces own energy consumption	Processing takes place via a waste incineration plant. Including discharge of fleece gas and flue gas residue	In current WWTP and extra biogas production, which reduces own energy consumption
Application	(fermentation) Compost biogas	Use slag residue as sand building material	Struvite (N, P, Mg and fertiliser)

In order to be able to carry out this evaluation, the functional unit of discharge and processing of 1 kg of food waste was chosen, in accordance with the STOWA study.
These methods include at least the 'consumables' (the chemicals and energy that are used), but also the infrastructure of a system that needs to be newly constructed. In this case it is only about the food disposer. Naturally, acquired extras, such as making compost, biogas and the like are taken into account.
No consideration was given to additional advantages and disadvantages in the economic and social field (complete sustainability analysis), but also not to what happens to components from the organic or residual waste scenario that are no longer needed (fewer containers, for example) such as food waste via the water can be drained. This was chosen in particular, because this decrease is considered negligible, as there will still be discharge of garden waste (and comparable) via these routes. Furthermore, the system limits as described in STOWA 2015-07 have been adhered to.

2.2.2 Inventory analysis

The data inventory analysis is entirely based on the research of STOWA and MerLAP 2002. In the MerLAP background document A14, published in 2002, the removal and processing of 1 tonne organic waste is taken as a starting point; the data is adapted to the functional unit chosen in this study (1 kg food waste). Many processes, which are described in Ecoinvent and to which the previous study refers, turned out to be outdated by now. With the limited budget and limited time available, these outdated processes have been replaced as far as possible by current processes available in Ecoinvent 2019. The exact quantities and selected processes from the Ecoinvent database are included in Appendix I.I. An explanation of this data collection is described in STOWA 2015-07 and MerLAP 2002. With the data inventory of scenarios, any behavioural changes other than adaptation to scenario are not included.

2.2.3 Impact assessment

The impact assessment was analysed using the Recipe-midpoint H method (Huijbregts et al, 2017). This method translates 22 environmental impact categories into three endpoint indicators (impact on human health, ecosystems and depletion of resources). It is not customary (scientifically substantiated) to subsequently express this using a single score (ecopoints), but often this data is also provided, because this simplifies interpretation.

2.3 Results

2.3.1 Differences with STOWA research

The STOWA 2015-07 report was used as a basis for this study. It has been decided to reproduce this study as well as possible, to revise it, and then to test the specific research questions from this study against the new model. Since the STOWA 2015-07 report has been used as a basis in its entirety, it is important to explain what causes the quite large differences.

Many datasets are involved in the preparation of an LCA. The inventory of consumables (how much energy, chemicals consumption and transport, etc.) has not changed. However, a life cycle inventory (LCI) database has been used to translate the use of these consumables into the LCA: EcoInvent (this is further explained in the introduction, section 2.1). The EcoInvent 2007 database was used in the STOWA report, while version 2019 was used in the current study. It can be assumed that there has been a major update of the processes and corresponding systems in the meantime. This also emerged from the fact that many of the processes used in this study turned out to have been discontinued and replaced by other processes. With the limited information and budget available, we converted these processes into processes that are adopted in the Ecoinvent database 2019. However, by replacing these processes, it was no longer possible to accurately reproduce the LCA model from the STOWA report. Moreover, the Recipe calculation method was also strongly revised in 2016 (Huijbregts et al., 2017), which may also explain that a considerable difference in impact is seen between these studies. The use of ecopoints to determine the impact can also play a role in this. Because the environmental impact of an average Western person changes over time, the environmental impact of 1 ecopoint also changes over time.

2.3.2 The basic scenarios (tree structures)

There are several options for discussing LCA results. It is desirable to show the differences in various impact categories (midpoint analysis), because this translation from data inventory to impact numbers is quite reliable. However, interpretation of the data often proves difficult, because how can we compare effects on these different midpoints? This is made possible by the introduction of single points, whereby one environmental score is obtained by weighing. Despite the fact that this score is easier to interpret, the disadvantage is that more uncertainty is added to the data set, due to the translation of different types of impact into one overall score. In this report it has been decided to present both variants.

Figure 3 provides a tree-structure representation of the ecopoints associated with the organic scenario. Green lines indicate a positive impact, red lines a negative. And the thicker the line, the greater the impact. This tree structure shows that a (positive) impact is expected in the sub-process of treatment. This is directly linked to the amount of biogas that is formed, which can be converted into electricity yield (as a result of natural gas, burned in gas engine process).

When food residues are discharged via the sewerage, with the intervention of a disposer, this model shows that this has a lower environmental impact than disposal via residual waste. However, this is not the case when it is compared with disposal via organic waste. In practice, it appears that in high-rise buildings a lot of food waste is disposed of via the residual waste route. However, this can also be the case locally in low-rise buildings. There are even municipalities that are considering no longer collecting waste separately. It is therefore relevant to properly estimate for each situation which disposal method should be compared. Additional research, with more insight into psychology / sociology, may provide more insight into this.

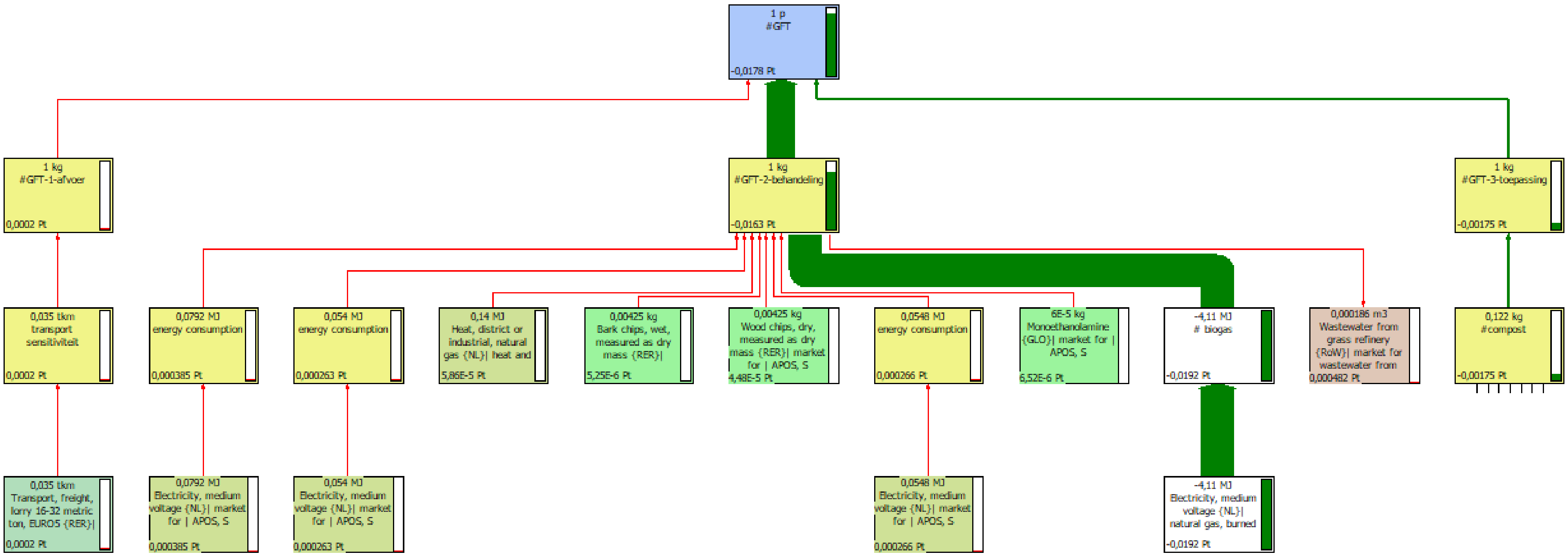


Figure 3 Tree structure representation of organic scenario (calculated with Recipe Endpoint H method. Green lines reflect a positive impact, red a negative. The thicker the line, the greater the relative impact.

A tree structure has also been drawn up for the sewerage scenario, in which food residues are removed via the sewerage (using a food waste disposer) (Figure 4). In accordance with the organic scenario, the most environmental gains are achieved by the formation of biogas, which can both deposit biogas (in sub-process application) and have prevented emissions (energy) because it can be used in own operations (in sub-process treatment). Nevertheless, there are also other factors that make a significant negative contribution to the environmental impact, such as the food waste disposer and total energy consumption.

A tree-structure representation of the environmental impact for the residual waste scenario is shown in Figure 5. To increase readability, only processes with an impact greater than 0.5 are presented; for a full version, please consult Annex I.II. Disposing of organic waste via residual waste has a negative impact on the environment, despite the fact that a small environmental gain is achieved by using the residual slag as sand (-6.6% environmental impact). Mainly the energy consumption for the waste processing installation (82.4%) and the transport for the disposal of organic waste (20.2%) are responsible for the high environmental impact.

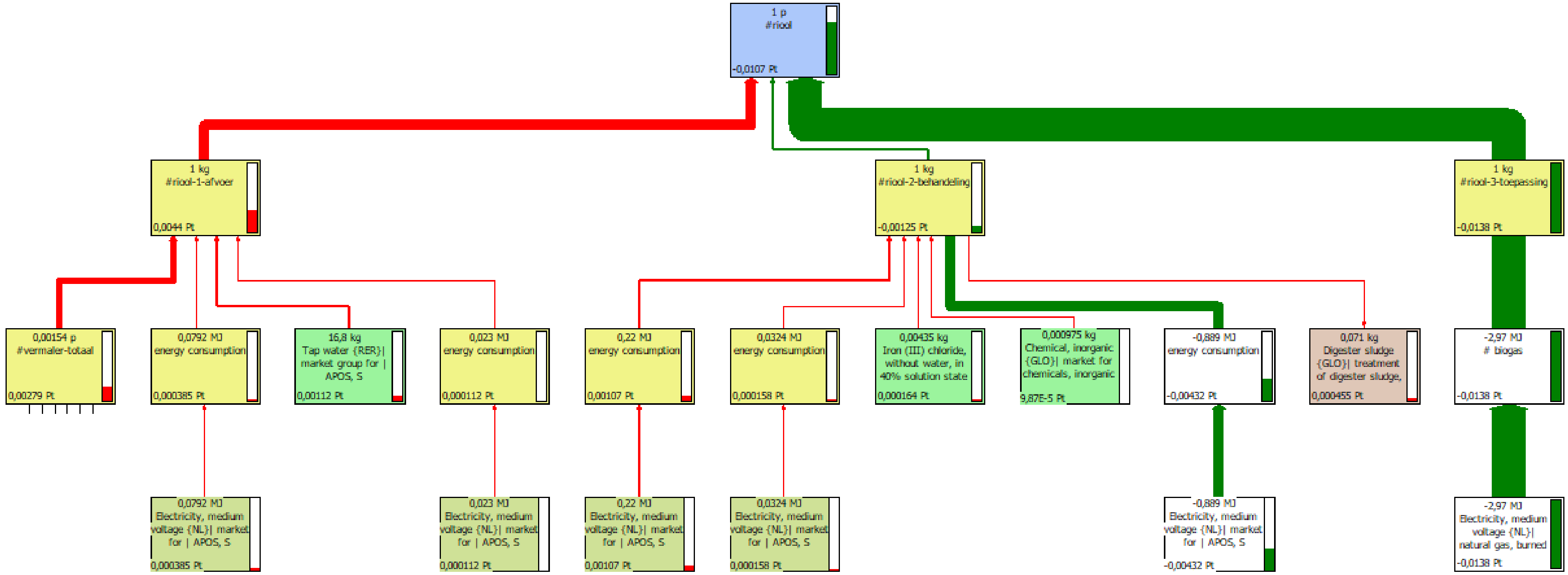


Figure 4 Tree view of sewerage scenario (calculated with Recipe Endpoint H method). Green lines reflect a positive impact, red lines a negative one. The thicker the line, the greater the relative impact.

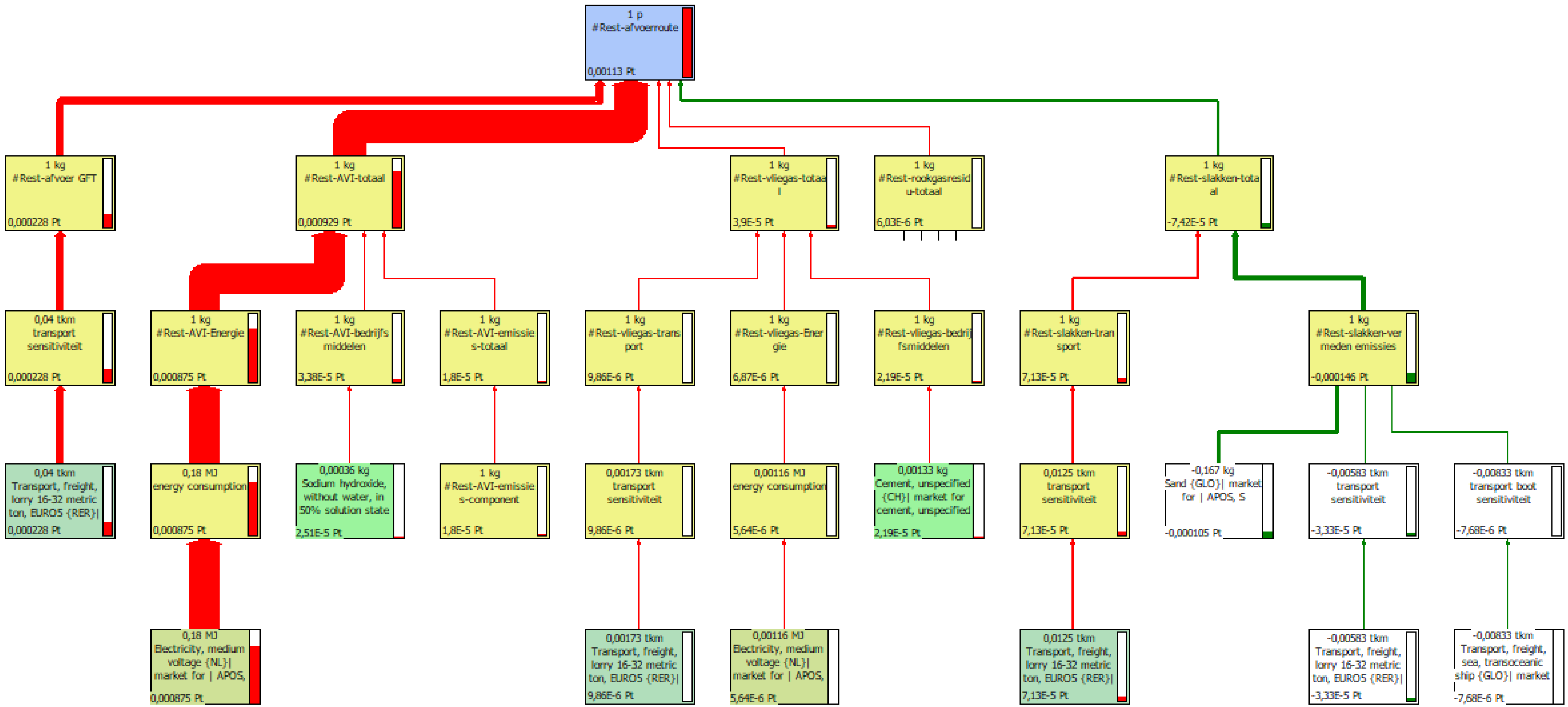


Figure 5 Tree view of the residual waste route scenario (calculated with Recipe Endpoint H method). The threshold for display was a contribution> 0.5%. Green lines reflect a positive impact, red lines a negative one. The thicker the line, the greater the relative impact.

2.3.3 Impact categories

All scenarios were evaluated over 22 midpoint categories, as summarised in Figure 6. In this model, the organic scenario scores predominantly better than the sewerage scenario. There are three exceptions to this: namely for the midpoints ionising radiation, eutrophication in freshwater and land use. Both scenarios even contribute to an improvement of the environment at various midpoints level. This is the case, for example, for global warming, ozone formation, acidification and depletion of fossil resources. The residual waste route generally scores on all midpoints with an impact deteriorating the environment; this is especially true for the ionising radiation and ecotoxicity midpoints in particular.

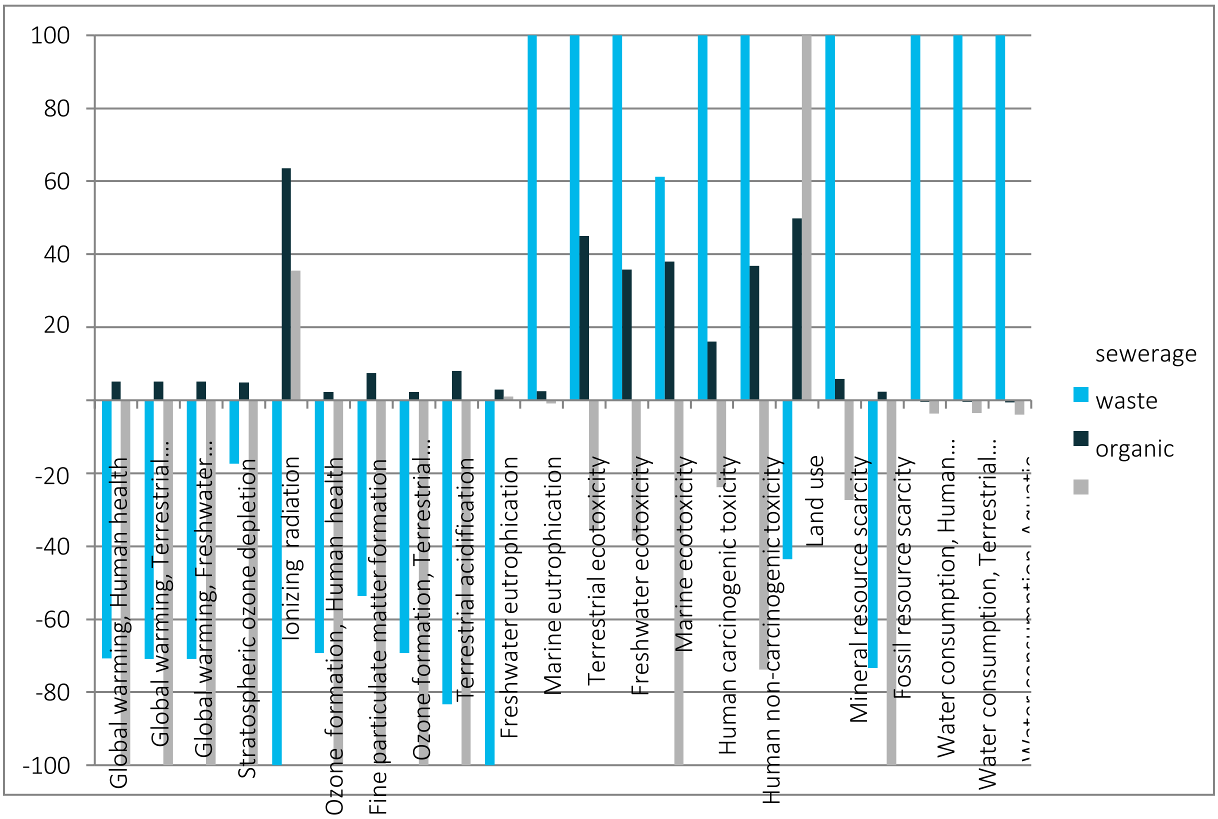


Figure 6 Characterisation among midpoint analysis of the sewerage, residual waste and VFG scenario (values are expressed in percentages, with the greatest impact shown as 100%).

2.3.4 Sensitivity analysis

For various parameters it has been investigated how large their influence is on the LCA result: a so-called sensitivity analysis. These parameters are varied to see to what extent this leads to a different environmental impact. The selection of parameters arose on the basis of the 'hot irons' in the tree structure diagram of the different scenarios, new insights from this research (described in Muñoz Sierra and Castro-Gama, 2020) and on parameters for which (rough) assumptions had to be made. because more accurate data was not available. The explanation is given per parameter.

Given that electricity consumption has a significant degree of impact, it is interesting to explore the environmental impact of the different energy sources on these scenarios. It is important to realise that the electricity that is generated within the scenario comes from biogas. So only purchased electricity is included in the sensitivity analysis.

Table 2 shows that the impact can change considerably. Among the tested energy sources, the difference for the organic scenario is a maximum of ~5% and for the sewerage scenario ~23%. The residual waste scenario is considerably influenced by the type of energy source that is chosen: the impact can, for example, decrease by 80%. This sensitivity study shows that the choice for a different (greener) source of energy does not lead to a significant different consideration.

Table 2 results of sensitivity analysis in ecopoints: form of electricity generation

Scenario	Basis: Market (medium)	Gas (medium)	Mark-et (high)	Wind (high)	Nucle-ar (high)	Sun (low)
Organic	-17.8	-17.9	-17.9	-18.7	-18.7	-18.5
Sewerage	-10.7	-10.6	-10.6	-8.26	-8.25	-8.95
Waste	1.13	1.09	1.11	0.3	0.298	0.535

In the current study, published in Muñoz Sierra and Castro-Gama, 2020, it has been shown that water consumption can be drastically reduced (>40%) to an average of 10L per day (per kg of food waste). The impact of this research result has also been evaluated. This not only includes the environmental impact of tap water use, but also the energy it takes to pump this volume. We have made a simplified assumption that there is a linear relationship between the volume to be pumped and the energy costs. Reducing water consumption will increase the environmental benefits through the sewerage scenario (Table 3). Of course, reducing water consumption only affects the sewerage scenario and can further reduce the environmental impact in this model.

Table 3 results of sensitivity analysis in ecopoints: water consumption. The ecopoint score for the organic and residual waste scenario is -17.8 and 1.13 ecopoints.

Scenario	Basis: 16,8 L	13L	10L	5L	1,2L
Sewerage	-10.7	-11.0	-11.2	-11.6	-11.8

In the model for the sewerage scenario, the food waste disposer has an impact of 26%, which is a significant share. When the lifespan can be extended, or more food residues can be processed in one day (without this having an impact on the lifespan), the impact of the food residues per functional unit (kg of food residues) is lower. When double the amount of food waste is processed, the environmental impact improves by about 20% according to this model (Table 4). It would therefore pay to optimise the use of this food waste disposer. This can be achieved by extending the lifespan, but possibly also by collective use of a disposer. For example, it could be considered to have several apartments disposed of their waste via one disposer. The collective use of a disposer does have some caveats: such as who is responsible (if it breaks), ease of use is less, safety issues, do we then throw away just as much food waste and is the waste neatly limited to just food residue? In other words, the behaviour of the user then plays an important role. Naturally, this sensitivity analysis only relates to the sewerage scenario.

Table 4 results of sensitivity analysis in ecopoints: effectiveness of the disposer (how much food waste can it process during its lifetime). The ecopoint score for the organic and residual waste scenario is -17.8 and 1.13 ecopoints.

Scenario	Basis (100%)	150%	200%	400%	800%
Piece of disposer per kg of food waste	0.00154	0.001155	0.00077	0.00385	0.00193
Sewerage	-10.7	-11.4	-12.1	-12.8	-13.1

In the STOWA 2015-07 report, table 3.9 shows the energy consumption during fermentation and post-composting. An addition to this, 'in practice' the energy consumption for the food waste is lower than for the total organic waste. The assumption that energy costs for fermentation of food waste and organic waste are the same is therefore an overestimation. The energy consumption related to fermentation, in the organic scenario, has therefore been studied in a sensitivity analysis. This model shows that this hardly has any effect on the environmental impact of the organic scenario (Table 5); a 50% reduction in energy consumption improves the environmental impact by only ~ 1%.

Table 5 results of sensitivity analysis in ecopoints: energy consumption for fermentation and post-composting. The ecopoint score for the sewerage and residual waste scenario is -10.7 and 1.13 ecopoints.

Scenario	Basis (100%)	75%	50%
Kwh fermentation	0.0214	0.01605	0.0107
Kwh post-composting	0.015	0.01125	0.0075
Organic	-17.8	-17.9	-18

The composition of compost is determined in the STOWA report: components such as P, N K, peat, etc. are included. These components can be used useful elsewhere, for example as struvite. The prevented emissions are listed as the components that are actually replaced (the replacement value). The research by Bolzonella et al., 2003 shows that there can be large variation in N and P content. The tree structure analysis (Figure 3) showed that compost has an impact of approx. ~10%; a sensitivity analysis therefore seemed necessary. We included the mean values from Bolzonella et al, 2003, as well as the minimum and maximum N and P values from the literature review described in this article. Interestingly, the ratios in which N and P vary remained comparable across the different studies included in this literature review. It was therefore decided to take the average of this ratio and thereby also adjust all other components that occurred in it (so not only N and P, but also Mg, K, Peat, etc.). The ratios of these assumptions and the results thereof are shown in Table 6. The effect of the replacement value is defined as '1' in the basic scenario and then adjusted pro rata for the sensitivity analysis. No impact change is observed for the sewerage scenario, because no struvite deposition takes place in this scenario. Since there is no sale of compost in the residual waste and sewerage scenario, this scenario is of course not affected when the replacement value is adjusted.

Table 6 results of sensitivity analysis in ecopoints: effectiveness of compost. The effect of the replacement value is defined in the basic scenario as '1' and then adjusted proportionally for the sensitivity analysis. The ecopoint score for the sewerage and residual waste scenario is - 10.7 and 1.13 ecopoints.

Scenario	Basis	Bolzonella 2003	Minimal value	Maximal value
Replacement value	1	0.625	0.25	4.2
Organic	-17.8	-17.2	-16.5	-23.5

When the organic waste is disposed of via the organic and residual waste scenario, transport takes place by truck. The tree structure of the residual waste scenario (Figure 5) shows that transport is responsible for ~20% of the environmental impact. The distance of organic waste transport by truck has only a minimal effect on the total environmental impact of the organic scenario, but it is significant for the residual waste scenario (Table 7). Of course, adjusting the distance over which a truck has to travel with 1 kg of organic waste has no effect on the sewerage scenario. However, the overall picture of these scenarios does not change as a result of different transport distances.

Table 7 results of sensitivity analysis in ecopoints: transport by truck for disposal. The basic value for the organic scenario is 35 km, for residual waste it is 40 km. The ecopoint score for the sewerage scenario is -10.7 ecopoints.

Scenario	10 km	20 km	35 km	40 km	60 km
Organic	-18.0	-17.9	-17.8	-17.8	-17.7
Residual waste	0.957	1.01	1.1	1.13	1.24

2.4 Conclusion

There are various alternatives for the disposal of food waste; examples are via organic waste, residual waste or via the sewerage. Disposal via organic waste or sewerage is an environmental gain, given the formation of compost, among other things. Disposing of food residues via the residual waste route has a negative impact on the environment. The disposal of food waste is mainly considered in high-rise buildings, where food waste is mainly disposed of via residual waste. In this model, the removal of food residues via the sewerage scores significantly better than the removal via residual waste. The quality of the compost and the grinder in particular seem to have a major impact on the total environmental burden. The advice is therefore to focus primarily on possibilities to reduce the (environmental) burden of disposers on the disposal: this can be done by extending the lifespan or possibly using a disposal collectively. It must then be investigated whether smart choices in food waste that may or may not be disposed of can improve the quality of compost. Additional research into the behaviour of users, and whether food residues are disposed of via the residual waste route or organic route, should provide more insight.

3 Legal and governance aspects

3.1 Introduction

3.1.1 Motivation

As stated earlier, a food waste disposer (FWD) grinds food waste with water into a liquid waste material which is then discharged into the wastewater. The use of a FWD can significantly reduce the flow of vegetable and fruit (VF) waste in the residual waste. This is interesting, given that the wet fractions of organic waste can influence the processing of dry fractions. In addition, collection via the sewerage may also have composting benefits. However, the use of a FWD has so far been banned in the Netherlands. This chapter will discuss the background to this ban and the exceptions to it (sections 2 and 3). Subsequently, it will be discussed how the use of a FWD may fit into circular thinking and how this ties in with current policy. In the last two sections of this chapter, the risks and responsibilities in the installation of FWDs are discussed.

3.1.2 Method

This chapter has been compiled on the basis of grey literature, white literature and interviews and discussions with relevant authorities.

3.2 Waste sorting in the Netherlands

3.2.1 Waste sorting in the circular economy

In the Netherlands and Europe, the circular economy is prominent on the social and political agenda. At the end of 2012, the Coalition Agreement stated that the government is striving for a circular economy and that it wants to stimulate the (European) market for sustainable raw materials and the reuse of scarce materials. This is elaborated in the 'From Waste to Resource' (VANG) programme of the Ministry of Infrastructure and the Environment (I&M, 2013, 2014). The VANG programme includes policy objectives with regard to dealing with natural resources; economical use of raw materials; smart product design; using products for longer and multiple times; and the optimal use of residual flows (CPB, 2016). A number of these policy goals have been made concrete in target values for recycling and prevention. For example, the cabinet is aiming for separate household waste processing of 75% of the waste by 2020 (I&M, 2014).

These goals are in line with the Dutch policy tradition for dealing with waste flows. Since 1979, a desired waste hierarchy 'the ladder of Lansink' has applied here. The general idea of this ladder is that less environmentally harmful waste treatments should be preferred to more environmentally harmful waste treatments. The ladder was succeeded in 2008 by the European Waste Framework Directive. The following waste hierarchy applies here: (i) prevention; (ii) reuse; (iii) recycling; (iv) incineration with energy recovery; (v) incineration without energy recovery; and (vi) landfill (CPB, 2016).

Ambitions are also expressed at the municipal level in the field of waste separation and recycling. In the 'Public Framework for household waste 2025' it was stated that the municipalities and municipal waste companies aim for 75% waste separation and then want to take a next step towards an almost complete circular economy, which is worthwhile for those who contribute to it. Each municipality has the freedom to make its own assessment, based on the specific situation and circumstances, when opting for separate collection of mono-flows or 'smart mixtures', or for collection of residual household waste followed by subsequent sorting (RWS, 2017)[1].

3.2.2 Household waste flows

In order to be able to recycle more at a national level, improvements can be made in particular in the recycling percentage at consumers' homes. A characteristic of consumer waste flows is that it concerns mixed waste flows and waste flows with a small size per location. As a result, recycling household waste is relatively expensive compared to other sectors (e.g. industry) due to higher transport costs. In addition to higher collection costs, this also concerns the effort that households have to make to sort waste. Depending on spatial conditions and the available time, these transaction costs can differ considerably between different (types of) households. Households in larger cities often recycle only 30% of the waste, while households in smaller cities or rural areas often recycle more than 50% (Dijkgraaf and Gradus, 2014).

In addition, the incentive for households to sort waste is limited because they pay a fixed amount per year for the collection and processing of residual waste. Since filling the 'grey bin' does not entail any additional costs, there is currently no financial gain for households from waste sorting (CPB, 2016).

3.2.3 Sorting at the source

In the Netherlands, household waste is sorted on the basis of the ‘sorting at the source’ principle. This has a long tradition, especially for solid waste. In most households, this separation concerns organic waste (vegetables, garden and fruit waste), paper, glass, small chemical waste, etc. The separation enables efficient processing and high-quality reuse of these flows. The wet waste stream, originating from human metabolism and household activities, is collected via the sewerage and processed at the wastewater treatment plant (WWTP) (Parliamentary Papers 27664: 40, 2005).

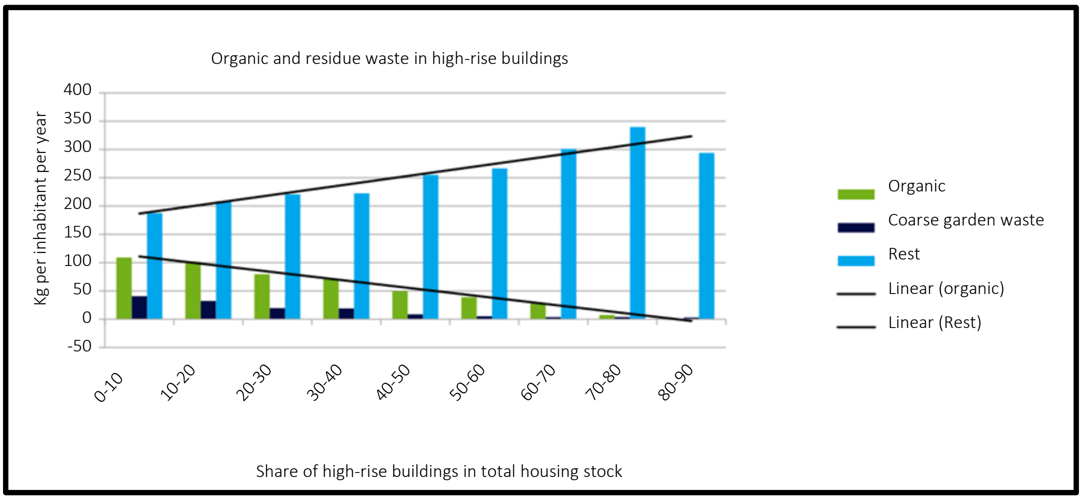
As a rule, waste sorting is reasonable when the additional costs for separation are lower than €45 per tonne compared to the costs of collection and processing of the residual waste. This is certainly the case for organic waste (RWS). Separated organic waste is processed into compost. If no sorting takes place at the source, it will become so contaminated that this is no longer possible. Recycling of organic waste is therefore only possible if sorting separation takes place. In addition, the wet fractions of organic waste also influence the recycling of dry components in residual waste (RWS, 2017).

Organic waste collection

In 2012, 50% of household waste was separated. Organic waste is the fraction with the greatest potential for improvement: 38% of the kilograms of residual waste in 2012 still consisted of organic waste (RWS, 2013). An inventory of various studies by the Waste Companies Association shows that the majority of food residues (vegetable and fruit waste, organic waste) still end up in residual waste. The amount of food remains in residual waste is estimated at 53-75 kilograms per inhabitant per year (Dutch Waste Management Association, 2014). When processed via the residual waste route, composting is no longer possible.

[1] However, this position does not mean that organic waste mixed with the sewage water may be transported to the WWTP. This may only be mixed in a separate processing stream (see section 3).

The Dutch Waste Management Association also concludes that there are few municipalities where organic waste is collected throughout the city. The collection of organic waste in high-rise buildings also appears to be a challenge for municipalities (Dutch Waste Management Association, 2014). Figure 1-1 shows that the higher the share of high-rise buildings in an area, the more residual waste is collected. At the same time, the amount of organic waste is actually decreasing. This difference can be partly explained by the fact that people in high-rise buildings generally do not have a garden (waste). Another possible explanation is that more organic waste disappears into residual waste.



Source: Based on data from CBS 2014 and Syswov 2012.
Figure 1-1: Collection of organic waste and residual waste in high-rise buildings (Dutch Waste Management Association, 2014, p. 13).

3.3 FWDs

3.3.1 Legislation

The use of a FWD can be an alternative to the collection of organic waste from households. FWDs, however, are banned in the Netherlands. The ban on discharge via a FWD was included in the Model Discharge Ordinance Sewerage of the VNG in 1987. This was used by almost all municipalities and provided regulations that discharges into the sewerage system had to comply with. These regulations were drawn up at the time to protect the sewerage system; in the interest of an efficient operation of the waste treatment; and to protect the quality of surface water (Parliamentary Paper 27664: 40, 2005).

These rules were taken over into national legislation during the implementation of the European Urban Wastewater Directive (EU/91/271). This concerned both wastewater from households and from business activities. The ban on discharging through a food waste disposer can therefore be found in various decrees under the Environmental Management Act (Parliamentary paper 27664: 40, 2005).

The currently active 'Environmental Management Activities Decree' also shows that wastewater containing waste materials that has been cut by cutting or grinding equipment may not be discharged (see Article 3.131, paragraph 3, section 3.6.1). This decision is further explained on the website of the InfoMil Knowledge Center (Rijkswaterstaat). Private individuals are not allowed to discharge wastewater through a food disposer into the wastewater sewer or septic tank (InfoMil, n.d.).

Trade restriction

In 1997, the ban was brought up for discussion by the American company In-Sink-Erator / Emerson before the then Minister of Housing, Spatial Planning and the Environment De Boer. In-Sink-Erator / Emerson argued that there was a trade barrier to the purchase and sale of food waste disposers. This has not led to a change in policy, as the ban does not relate to the purchase or possession of a disposer, but only to discharge into the sewerage system. Therefore, the ban cannot be considered a trade restriction according to the ministry. In practice, the prohibition means that food waste disposers are hardly used (Parliamentary Papers 27664: 40, 2005).

<u>Ban</u>
Following the 'Discharge of household wastewater' decree, the ban has been enforced. The State Secretary of VROM explained this in 2005 (Parliamentary papers 27664: 37 & 40, 2005). The most important arguments cited here is that the Dutch waste policy is based on the starting point ‘waste sorting at the source’. Disposing of solid waste via a 'wet route' is at odds with this and abandoning this principle was not seen in the interest of waste processing and the environment. In addition, the discharge of ground food residues creates an extra burden for the wastewater system. An increase in the tax on this system will lead to an increase in emissions both via the overflows and via the effluent discharges (partly due to the increase in organic waste in the wastewater). This is considered undesirable by the ministry. In 2006, the then State Secretary Van Geel said about this: *‘The wastewater system is burdened with the discharge of ground food residues. Any increase in the load on this system will lead to an increase in emissions from this system, both via the overflows and via the effluent discharges. I consider this undesirable from the standstill principle.’*

More recently, STOWA has also studied the different processing routes of food waste. This was done by means of a Life Cycle Assessment (LCA) of the various food waste processing routes. The routes studied are: removal via residual waste followed by incineration in a waste incineration plant (WIP); removal via source-separate collection of organic waste, followed by fermentation and composting; discharge after grinding via an unseparated sewerage system and processing in a WWTP; disposal after grinding via a separate sewerage system and processing in a wastewater treatment plant. This study has shown that source-separated collection followed by composting and fermentation is the most environmentally hygienic method of waste management (Odegard et al., 2015).

However, this LCA only focuses on the environmental impact of the different waste routes. Other advantages and disadvantages, such as price or convenience, are not included. In addition, the LCA has been drawn up from the perspective of the current system. We looked at marginal changes in which the costs for FWDs, for example, were included, but not those for the waste trucks (which are already in use to collect the waste). In such an ‘attributional’ or ‘incremental’ LCA, no account is taken of system changes as a result of a transition to large-scale application of FWDs. This LCA therefore does not indicate how a system in which the ‘new water chain’ (also called new sanitation) is applied, relates environmentally to the existing system. Nor is a distinction made between different locations in the Netherlands or the differences between low and high-rise buildings.

3.3.2 Possibilities to lift the ban

In current legislation and regulations, a number of considerations have been drawn up that precede a provision on source separation of household waste. These are set out in the National Waste Management Plan (LAP3) (RWS, 2017). Based on the aforementioned LCA study, Rijkswaterstaat concludes in the LAP3 that source-separated waste collection, followed by composting and fermentation, is the most environmentally hygienic way to deal with organic waste. In response to this, it has been stated in the LAP3 that the results of the LCA study do not give cause to adjust the current regulations regarding the removal and processing of food waste. There are currently two pilots with FWDs in Amsterdam and Apeldoorn. However, Rijkswaterstaat does not consider setting up new pilots desirable as long as the existing ones do not lead to new insights (RWS, 2017, p. 100).

This is striking, given the aforementioned generic approach of the LCA and the regional differences in collection and success with regard to waste separation. The LCA itself therefore states: ‘The current LCA study can serve as a basis for a study on environmental impacts for a specific location, including system changes’ (Odegard et al., 2015, p. 69). This advice does not seem to align with the policy pursued, which discourages further pilot studies.

Nevertheless, municipalities and other parties involved retain the option of excluding areas from separate collection of specific waste materials (e.g., organic waste). Municipalities therefore leave room to give their own interpretation to waste sorting at the source within the national frameworks and objectives (RWS, 2017). This calls for an amendment to the local sewerage ordinance, which requires an area-specific interpretation (Ververs, 2019). However, this means that the wastewater is collected and processed separately and therefore not at the WWTP.

Main obstacles to lifting the ban are:

- Starting point for waste policy: separate collection. This starting point seems to stem from a reuse perspective.
- Extra tax on the wastewater system: both risk of blockage and extra emissions during processing and risk of overflow with this wastewater.
- An LCA study has shown that source-separated collection followed by composting is the most environmentally hygienic method of waste management.

Possible opportunities for policy change:

- Successful implementation in pilots seems to offer an opportunity to change policy.
- Being able to demonstrate that the mixed waste flow does not cause any additional burden for the WWTP is an important part of a possible policy change.
- FWDs seem particularly interesting for areas with many high-rise buildings or where no organic waste collection takes place.
- Municipalities have the option to exclude areas from separate collection of specific waste (e.g. organic waste). Municipalities therefore leave room to give their own interpretation to waste separation at the source within the national frameworks and objectives (RWS, 2017). This means that the wastewater is processed in a separate stream (not via the WWTP).

3.4 Division of responsibilities and costs & benefits

Besides the fact that the use of FWDs has an impact on the waste flows from households, there are also other (possible) implications of this technique. With the introduction of FWDs, new ones are also coming responsibilities, including responsibility for the risks associated with use, for the investment in equipment and for noise pollution. In addition, new benefits may arise from the large-scale use of FWDs.

3.4.1 Risks of use

Risks related to the use of FWDs are mainly related to blockage of the drainpipes. In general, this risk is the responsibility of the building owner. The sewerage manager is responsible up to the plot boundary. In the case of a compulsory purchase of a FWD (for example in a new neighbourhood), the maintenance of the pipework up to the property boundary turns out to be a legal grey area (this is not the case in the case of voluntary participation). This can be solved by extending the responsibility of the sewerage manager with a private law agreement on management and maintenance. In the case of a pilot study, this may be the case. In such a case, the sewerage manager himself or a subcontractor can take over the management of the building sewerage. In a case of a pilot study, this can be done to minimise the risks for the homeowners when participating in the pilot.

3.4.2 Responsibility for equipment investment

The extra investments in equipment can be divided in various ways. Who will cover this investment depends in the first place on the ownership of the home. If this is an owner-occupied home, these costs seem to be mainly borne by the owners themselves. However, when this falls within a pilot or new-build project, where the installation of FWDs was included in the pilot, this can lead to friction. Article 122 of the Housing Act stipulates that you may not ask for more from homeowners than is laid down in the Building Decree. As a result, homeowners (or potential homeowners in the case of new construction) cannot be forced to install an FWD, unless this is included in the building code. Whether this poses a problem also depends on the division of responsibilities between the future residents, the project developer and the municipality (see Chapter 5). When the project developer offers a total system, where everything is already included in the purchase price, this problem can be avoided. An additional advantage is that everything can be properly coordinated (Stowa, 2019).

Similar problems can also be avoided in the case of rental properties. By already installing the FWDs in the homes, purchase costs can be included in the rental price. The tenant then knows in advance what he / she is signing for.

3.4.3 Noise pollution

The NEN 1070 includes a general maximum noise standard that applies to FWDs of 40 dB in the (adjacent) spaces. In the case of high-rise buildings, it is also necessary to comply with the Building Decree, whereby a maximum noise standard of 35 dB applies in the adjacent apartment. In addition, a home deposit or SWK guarantee often applies to owner-occupied homes, including a standard for the maximum noise within a home.

FWDs generally make much more noise than this 40 dB (Stowa, 2019).

3.4.4 Distribution of benefits

How the benefits of more efficient fermentation are realised depends on the project agreements that are made. There are two important benefits to mention. First, there are the benefits of waste fermentation. How these will be distributed is difficult to estimate based on current pilots and projects. These projects are relatively small, so that the differences at the WWTP are/will hardly be noticeable. When there is a separate fermentation, separate from the WWTP, these benefits are more measurable. However, in the case of a pilot project, these are still of minimal scale.

When the use of FWDs is scaled up, the benefits may initially end up at the WWTPs. These may flow back to citizens and housing corporations because citizens receive a discount on their waste levies to compensate for the installation costs (possible measure).

Other benefits that can be obtained from the use of FWDs can be described as not incurring costs for the collection of organic waste streams. When the use of FWDs is implemented on a large scale, the costs for collecting organic waste will decrease (Ververs, 2019). The separate collection of waste streams is a high-cost item, which makes far-reaching recycling of streams more difficult. A literature study by the CPB (2016) showed that less recycling of household waste is generally better than more[2]. This insight is mainly based on the relatively high costs that separate collection of waste entails. This means that more recycling of residual waste is not profitable at a social level. In addition, the external effects (environmental damage) of waste processing are too low to justify a higher percentage of recycling (CPB, 2016). The use of a FWD can therefore potentially yield benefits with regard to more efficient digestion, but also with regard to saving costs for separate collection.

[2] The CPB literature study did not investigate whether recycling is profitable at all, but whether more recycling is profitable (CPB, 2015).

3.5 Examples of pilot projects

Division of responsibilities: Reitdiep, Groningen

At the Reitdiep plot construction project in Groningen, the planned installation of FWDs in a self-build plot project caused problems. In this project the installation of FWDs was desired by the plot owners themselves. However, the installers turned out to charge a much higher price for the installation of this than expected in advance, causing a resident to legally contest the installation of an FWD. As a result, the municipality is now aiming for a voluntary participation (Stowa, 2019).

Governance: Pilot Gaasperdam

Goal

From 2012-2015, Waternet has been busy preparing a pilot study into FWDs. The aim of the study was to measure the effect of the use of FWDs on sewerage functioning. The underlying larger vision of the future with regard to the circular economy was a motive for setting up this project. The advantage of using an FWD is that it can contribute to a transition to a circular economy, without requiring a behavioural change from the user. In addition, the project also had interfaces with issues surrounding decentralised wastewater treatment, as the wastewater in this project was decoupled and composted separately. The choice for this decoupling was also practical: the location was suitable for decentralised fermentation because it was located far from the WWTP. In addition, because it was a small pilot study (200 households), the effects would be difficult/impossible to map out for the WWTP.

Design

The chosen location for the pilot was an existing construction site in Amsterdam Southeast. It concerned a series of flats built around 1970. Participating parties in the pilot were the city districts (now defunct), the sewerage manager (Waternet), InSinkerator, the waste energy company, and residents. During the preparation of the project, contact was sought with the housing corporations, but in the end, they were not interested in participating. That is why private homes have been chosen. Every home would receive an FWD within the pilot and this would also be installed and possibly maintained. The purchase costs of the FWDs would be covered by InSinkerator in the project.

Difficulties

Despite extensive discussions in preparation, the project did not proceed. One of the main obstacles to this was ownership of the project. Waternet, the initiator of the project, is responsible for the sewerage system, but did not feel suitable as a project leader. This role would be better suited to the city districts, as they are involved in all steps of the process. However, in this period the city districts were mainly an executive organisation, which operated more on the basis of current practical knowledge and were less focused on the future. At the time, the central city also had a project group that could initiate such a project, but they were also unable to do this.

4 References

4.1 Literature

Baayen, H. (2000) Eco-indicator 99; manual for designers; A damage oriented method for Life Cycle Impact

BOLZONELLA, D., P. PAVAN, P. BATTISTONI and F. CECCHI 2003. The under sink garbage grinder: A friendly technology for the environment. Enviromental Technology Volume 24 2003 issue 3.

CENTRAAL PLANBUREAU - CPB, 2016. Een verkennend onderzoek naar de haalbaarheid en wenselijkheid van doelstellingen met betrekking tot recycling en preventie van huishoudelijk afval. In: MILIEU, M. V. I. (ed.). Den Haag: Centraal Planbureau.

DIJKGRAAF, E. en GRADUS, R., 2014,The Effectiveness of Dutch Municipal Recycling Policies, Tinbergen Institute Discussion Paper 14-155/VI.

ODEGARD, I., BERGSMA, G., BERG, R. & TELKAMP, P., 2015. Huishoudelijke voedselresten in de afvalwaterketen. Levenscyclusanalyse van de verwerking van GF-afval en afvalwater. Bennekom: Tauw, CE Delft, Stowa, Stichting Rioned. Stowa 2015-07

MerLAP (milieueffectrapport landelijk afvalbeheerplan), 2002, Achtergronddocument A14 uitwerking "GFT-afval". Afval Overleg Orgaan 2002.

MINISTERIE VAN INFRASTRUCTUUR EN MILIEU, 2014, Kamerbrief invulling programma Van Afval Naar Grondstof, IENM/BSK-2014/12161.

MINISTERIE VAN INFRASTRUCTUUR EN MILIEU, 2013, Van Afval Naar Grondstof – Uitwerking van 8 operationele doelstellingen, Bijlage 1 bij de kamerbrief Invulling programma Van Afval Naar Grondstof.

Muñoz Sierra and Castro-Gama, 2020. The impact of Food Waste Disposers on the indoor sewerage system. Final report of TKI OSKAR. KWR

RIJKSWATERSTAAT– RWS, 2013, Samenstelling van het huishoudelijk restafval: resultaten sorteeranalyses 2012.

RIJKSWATERSTAAT - RWS, 2017, Beleidskader Landelijk Afvalbeheerplan (LAP)3. Deel B - Afvalbeheer en overbrenging. In: RIJKSWATERSTAAT (ed.). Den Haag: Ministerie van Infrastructuur en Milieu. B3.4.3

RIJKSWATERSTAAT - RWS, g.d., Afvalstoffenkaart gft/swill en groenafval. In: RIJKSWATERSTAAT (ed.).

STOWA. Verslag COP VRV&VR (Voedselrestenvermalers en Vacuümriolering). COP VRV & VR, 31 januari 2019 Amersfort. Amersfoort: STOWA.

STOWA rapport 2015-07: Huishoudelijke voedselresten in de afvalwaterketen.

VERENIGING AFVALBEDRIJVEN. 2014 Startdocument Gft-inzameling omhoog: meer inzamelen in hoogbouw. ’s-Hertogenbosch.

4.2 Parliamentary papers:

Parliamentary papers 27664:40, 2005

Parliamentary papers 27664:37, 2005

4.3 Websites:

InfoMil, n.d., https://www.infomil.nl/onderwerpen/lucht-water/handboek-water/activiteiten/lozen-vanuit/voedingsmiddelen/gebruik/[Consulted on 29 April 2019]

4.4 Interviewee:

Rob Ververs, Project Developer Transitions Waternet. On 26 April 2019.

I.I Appendix: extensive data inventory

This appendix contains various tables that accurately describe the data inventory of the models used.

Table 8 Data inventory for organic scenario

Phase	Process	Unit	amount
Removal	Freight, lorry 16-32 metric ton, Euro 5	tkm	0.035
Processing	Avoided: natural gas burning in gas motor	MJ	4.11
	Occupation, industrial area	M2a	$8.1 \cdot 10^{-4}$
	Energy consumption	kWh	0.022
	Energy consumption	kWh	0.015
	Heat, natural gas	MJ	0.14
	Bark chips, wet, measured as dry mass	g	4.25
	Wood chips, dry, measure as dry mass	g	4.25
	Energy consumption	kWh	0.0152
	Monoethanolamide	g	0.06
	Emission to air: methane	mg	$1.1 \cdot 10^{-3}$
	Emission to air: dinitrogen monoxide	mg	46
	Emission to air: ammonia	mg	180
	Emission to air: nitrogen monoxide	mg	2.3
	Emission to air: sulphur dioxide	mg	10.7
	Waste treatment: wastewater from grass refinery	M^3	$18.6 \cdot 10^{-5}$
Application	Avoided: natural gas burning in gas motor	MJ	0
	Compost (see description in Table 9)	g	122

Table 9 Data inventory with regard to composition: representative of 1 tonne of compost

Peat production (Nordel)	kg	610
Nitrogen fertiliser as N (calcium ammonium nitrate production)	kg	28.6
Phosphate fertiliser, as P2O5 (triple superphosphate production)	kg	4.02
Potassium sulphate, as K2O	kg	39.1
Magnesium sulphate	kg	1
Magnesium oxide	kg	27.2
lime	kg	27.2

Table 10 extensive data inventory for the sewerage scenario

Phase	Process	Unit	Amount
Disposal	Occupation, industrial area	m2a	0
	Disposer (see description in Table 11)	piece	$1.54*10^{-3}$
	Energy consumption	kWh	0.022
	Tap water	kg	16.8
	Energy consumption	kWh	0.00639
Processing	Avoided: energy consumption	kWh	0.247
	Occupation, industrial area	m2a	$3.36*10^{-5}$
	Energy consumption	kWh	0.061
	Energy consumption	kWh	0.009
	Iron (III) chloride, in 40% solution	g	4.35
	Chemical, inorganic	kg	$9.75*10^{-4}$
	Emission to air: methane	kg	$2.3*10^{-3}$
	Emission to air: dinitrogen monoxide	kg	$5.49*10^{-6}$
	Emission to water: nitrogen	kg	$1.7*10^{-4}$
	Emission to water: phosphorus	kg	$-6.53*10^{-4}$
	Waste treatment: digester sludge municipal incineration	kg	0.071
Application	Avoided: natural gas burned in gas motor	MJ	2.97

Table 11 extensive data inventory for the production of 1 food waste disposer.

Phase	Process	Unit	Amount
Waste disposal	Steel and iron waste treatment: recycling of steel and iron	kg	0.12
	Inert waste (Europe without Switzerland) treatment of inert waste, sanitary landfill	kg	2.28
Emissions	Methyl ethyl ketone	kg	$4.1E{*}10^{-7}$
	Carbon monoxide	kg	0.02
	Lead	kg	$1.2{*}10^{-6}$
	Methanol	kg	$5.5{*}10^{-7}$
	Nickel	kg	$9.2{*}10^{-8}$
	Nitrogen oxides	kg	$5.3{*}10^{-4}$
	Sulphur dioxide	kg	$1.2{*}10^{-4}$
	VOC, volatile organic compound as C	kg	$5.2{*}10^{-3}$
	xylene	kg	$6.9{*}10^{-5}$
Process energy	Electricity, medium voltage RNA market group for	MJ	20.6
	Heat district or industrial, natural gas (glo)	MJ	10.2
Transport	Freight, lorry 16-32 metric ton euro 4,	tkm	2.6
	Sea, transoceanic ship, processing	tkm	9.77
	Lorry 16-32 metric ton euro 4	tkm	39.1
Packaging	Corrugated board box	kg	0.21
	Polystyrene, expandable	kg	0.04
	Polyethylene, high density, granulate	kg	$2.8{*}10^{-3}$
	Packaging film, low density polyethylene	kg	$3.6{*}10^{-3}$
Materials	Acrylonitrile-butadiene-styrene copolymer	kg	0..9
	Aluminium, primary, liquid	kg	0.26
	Aluminium scrap, post-consumer	kg	0.11
	Copper production, primary	kg	0.05
	Steel, chromium steel 18/8	kg	0.39
	Steel, unalloyed	kg	0.59
	Steel, low-alloyed, hot rolled	kg	0.99
	Steel, unalloyed	kg	0.28
	Steel, unalloyed	kg	4.28
	Steel, unalloyed	kg	0.26
	Steel, unalloyed	kg	0.96
Recycling	Steel and iron, recycling	kg	0

Table 12: extensive data inventory for the disposal of 1 kg of organic waste via the residual waste route

Subject	Processes	Parameters	Background information
AVI			
Collection	Transport truck	0.04 tkm	
			Distance 40 km
Land use	Occupation	$0.044*10^{-3}$ m^2/y	
Transport	Transport truck	$0.15*10^{-3}$ tkm	
			Business resources 2 g
			Distance 75 km
	Transport boot	0.42610^{-3} tkm	
			Chalk 0.71 g
			Distance 600 km
	Transport truck	0.035510^{-3} tkm	
			Chalk 0.71 g
			Distance 50 km
Energy	Electricity	5010^{-3} kWh	
Business resources	Chalk	4 mg	
	Sodium Hydroxide	360 mg	Corrected for active ingredient
	NH_4OH	49 mg	Corrected for active ingredient
	Active coal	30 mg	
Emissions to air	As described in Table 13		
Fly ash			
Land use	Occupation	0.05810^{-3} m^2/y	
Transport	Transport truck	1.72910^{-3} tkm	
			Business resources 13.3g
			Distance 130 km
Energy	Electricity	0.0710^{-3} kWh	
	Electricity	1.1610^{-3} MJ	
Business resources	Cement	1.33 g	
Emissions to air	As described in Table 13		
Emissions to soil	As described in Table 13		

Flue gas cleaning residue			
Land use	Occupation	0.13610^{-3} m^2/y	
Transport	Transport truck	0.086510^{-3} tkm	
			Residual dust 1.73 g
			Distance 50 km
	Transport boat	0.06510^{-3} tkm	
			Sand 1.3 g
			Distance 50 km
	Transport truck	0.04610^{-3} tkm	
			Sand 1.3 g
			Distance 35 km
Energy	Electricity	0.1810^{-3} MJ	
	Electricity	0.4310^{-3} MJ	
Business resources	Big-bag	5.7 mg	
	PE-cover	2.3 mg	
	Cover sand	1297 mg	
Slag			
Transport	Transport truck	$12{,}502510^{-3}$ tkm	
			Residual dust 166.7 g
			Distance 75 km
Emissions to soil	As described in Table 13		
Prevented emissions	Transport truck	5.834510^{-3} tkm	
			Residual dust 166.7 g
			Distance 35 km
	Transport boat	8.33510^{-3} tkm	
			Residual dust 166.7 g
			Distance 50 km
	Sand	166.710^{-3} kg	

Table 13 extensive data inventory for emission values in µg (unless stated otherwise in the table) for various process components of the removal of 1 kg organic waste via the residual waste route.

	AVI	Slag	Fly gas	
Emissions to	Air	Soil	Air	soil
Arsenic	0.868	0.53	-	0.17
Barium	46.48	28.4	-	18.19
Cadmium	0.78	0	-	0
Cobalt	0.56	0.34	-	0.22
Chromium	12.32	7.53	-	2.41
Copper	8.4	5.13	-	1.64
Mercury	1.2	0	-	0
Manganese	47.6	29.08	-	9.32
Molybdenum	1.232	39.89	-	12.78
Nickel	2.128	1.3	-	0.42
Lead	27.16	16.59	-	5.32
Antimony	0.588	3.95	-	0.12
Selenium	0.14	0	-	0.22
Tin	0.7	0.43	-	0.14
Vanadium	2.912	1.78	-	1.71
Zinc	42	25.66	-	8.22
Chlorine	1920	26832	-	6144
Fluorine	1300	7.8	-	35.1
Sulphate	-	43198.92	0.22	4752
Sulphur dioxide	4320	-	-	-
Nitrogen oxides	113.9 mg	-	-	-
Ammonia	5.7 mg	-	-	-
Carbon monoxide	37.97 mg	-	-	-
Hydrocarbons	9.49 mg	-	-	-
Dioxins	$9.49*10^{-8}$ mg	-	-	-
particulates	5.89 mg	-	-	-

I.II Appendix: full tee structure residual waste route