MSc Program
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Categorization and Optimization of Waste Collection Centers (ASZ) in the District of Mödling, Lower Austria

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Affidavit

I, **FRANZ PAUL MAYER DE LA ROSA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Optimization of Waste Collection Centers (ASZ) in the District of Mödling, Lower Austria", XXX pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have nor prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

Background: Waste management has become a global issue of ever-growing significance. Whether the present recycling system in the district Mödling, Lower Austria works efficiently remains unclear. This thesis aimed to evaluate the actual waste management system by on-site inspections, analysis of electronic data management (EDM) information and assessed potential improvements of the current system by introduction of different simulations.

Methods: Categorization of disposed waste among waste collection centers (ASZ), assessment of employed storage methods and calculation of extra drop-off fees were performed by analysis of EDM data of 2013 as provided by the district´s waste collection association. Material flow analysis (MFA) was used to assess the extent of different utilization methods applied. For detection of any weaknesses in the present recycling system with 21 ASZ, two simulations with a reduction to 3 (scenario 1) and 14 (Scenario 2) ASZ for the entire district were introduced and compared with the status quo. For both the present situation and the simulations the ASZ´ geographical distribution, the convenience for citizens (distance to ASZ, opening hours, fuel costs), the impact on environmental indicators (diesel consumption, carbon dioxide [CO_2] emissions) and accruing investment & operational costs were evaluated.

Results: Waste of 6 major groups with a total of 52 different subfractions could have been disposed at any ASZ using standardized and well-organized storage methods. In the entire district 35.307 tons (t) of waste were disposed (range between municipalities: 297 t - 6.914 t) with the highest proportion originating from the biogenic waste group followed by excavation waste, scrap waste, bulky waste, waste electrical & electronic equipment (WEEE) and hazardous waste. MFA indicates that most waste was composted with smaller amounts utilized by landfilling, incinerating, recycling, shredding or processing in waste electrical appliance (EAG) plants and refineries. The optimization approach revealed that the simulated ASZ amalgamations inconsistently changed individual distances to ASZ but were accompanied by a 3.9-fold (scenario 1) and 1.4-fold (scenario 2) increase in total travelled distance, fuel consumption, diesel costs and CO_2 emissions across the entire district. A decrease in total investment costs by 72% (scenario 1) and 18% (scenario 2) could be observed. Further, a reduction in both opening hours and operational costs of -93% (scenario 1) and -85% (scenario 2) was calculated for the simulations.

Conclusion: The present ASZ are probably operating efficiently in terms of waste collection. However, a reevaluation of the current opening hours with a moderate reduction in ASZ (scenario 2) across the district might lead to cost savings without significantly affecting the citizens willingness to drop off waste. Access to any ASZ should be granted independently whether or not ASZ are going to be amalgamated and is likely to be related with an increase of the population´s convenience.

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List of Abbreviations

ARA	Altstoff Recycling Austria AG
ASZ	Waste collection center(s)
EDM	Electronic data management
EAG	“Elektroaltgeräte” - waste electrical appliance
GHG	Greenhouse gas emissions
GIS	Geographic information system
GVA Mödling	Association of municipalities for tax collection and environmental protection in the district of Mödling
MSW	Municipal solid waste
MFA	Material flow analysis
MUM	Transfer Station Mödling
NÖ BAUW GesmbH	Niederösterreichische Beteiligungsgesellschaft für Abwallwirtschaft und Umweltschutz GesmbH
NÖLI	Appropriate measures for disposal of old cooking oils/fats
NÖ AWV	Niederösterreichischer Abfallwirtschaftsverein und NÖ Abfallverbände
RU3	Environmental economy and regional planning support of the State of Lower Austria
TC	Transfer coefficients
STAN	SubSTance flow Analysis
WEEE	Waste electrical and electronic equipment

1. Introduction

All human activities have always generated waste. At any city regardless its size across the world, waste is receiving an unexpected and a significant attention. Reducing its production has become a focus of many small villages and cities as they strive to reduce their environmental impacts. Cities are working arduously to minimize the amount of waste they generate and maximize the diversion rate of generated waste (Nagawiecki, 2009).

The establishment of a large number of waste collection centers (ASZ) in industrialized countries has thus aimed to collect larger amounts of waste to ensure recycling and waste treatment. The system for household waste recycling varies among countries but they have one final cause in common: they serve undeniably to collect waste through different separation methods. These facilities play an important role in achieving national recycling goals and most importantly they contribute to the mitigation efforts of preventing and reducing greenhouse gas emissions (GHG).

As the trend towards recycling grows, so does the need for increasing the efficiency of waste collection centers. One way of doing this is to adapt a local waste management system with ideas, theories, strategies, policies, norms, regulations and principles from the area of production engineering. By doing so, this implementation will thus enhance the performance and efficiency of waste collection centers. In addition, by introducing (and revising) existing laws, regulations and incentives many industrialized countries have contributed to the reduction of the GHG as well as by increasing the recycling rates. Austria reflects such a statement (Nagawiecki, 2009).

In Austria, all community inhabitants may dispose their specific wastes such as waste wood, scrap metals, waste of large size, and hazardous or electrical waste at local waste collection centers. ASZ are manned facilities where individuals can bring, sort and dispose their waste, assisted regularly by the employees. Different waste/ material fractions in the form of different products and materials (e.g. furniture, home appliances, wood, and garden waste) are placed in different large steel containers, depending on the type of product or material. This service is provided by each municipality and often located in a sub-urban area. It is mainly financed through fees for household waste collection (Sundina et al., 2011).

To identify gaps, deficiencies and weaknesses of present waste management systems, villages and cities have opted to undertake waste optimization studies with the goal of discovering precisely what makes up their waste stream. Armed with the data gained from waste optimization, these cities are restructuring their waste management systems to maximize waste diversion, thereby reducing waste management expenditures. Minimizing waste production and optimizing the waste collection system could reduce expenditures significantly. Waste optimization studies seek the opportunity to both reduce environmental impacts and financial expenditures by improving any waste management system (Nagawiecki, 2009).

1.1. Aim of Study and Objectives

Despite the growing importance of recycling centers in Austria, the overall performance that is actually achieved at these facilities has not yet been extensively studied. This prevents identification of possible weaknesses in practice and the opportunity to develop improvement measures. To assess these crucial issues, the waste management system in a representative district of Austria (Mödling) has been chosen and analyzed for this study and can be seen as a first step towards filling this knowledge gap.

In addition, this thesis addresses type and amount of annual waste collected, facilities and methods of collection. Location, access, and other characteristics were analyzed in view of learning the most for the establishment of future ASZ. The need for this research was mainly triggered by the lack of information about whether or not the ASZ are functioning in the most efficient manner. Therefore, the assessment of the ASZ in relation to their efficiency is crucial to understand the functioning and services provided of such centers in order to possibly identify potentials for improvements.

This comprises the following objectives:

- To accurately identify the geographical distribution of ASZ and other waste related centers
- To identify the type of waste that is accepted by each ASZ
- To identify the type and amount of the waste that is dropped off at each ASZ
- To identify the different employed methods for the collection/storage of waste fractions
- To prepare an overview of costs arising from these recycling centers
- To identify the drop-off fees for the customers;

The objectives of this thesis lead to 14 key research questions in order to accomplish the goals of this study:

1. Is the current geographical distribution of the ASZ acceptable?
2. What might be an ideally acceptable distance among households and the recycling centers?
3. Which type of waste is collected by each ASZ?
4. How much waste is collected by each ASZ?
5. What are the methods employed for the collection and storage of waste?
6. Are the employed methods well organized?
7. Are the employed methods suitable for the storage, collection, transportation, processing and disposal of waste?
8. How much was the investment cost of each ASZ?
9. How much are the operational costs?
10. How much are the extra drop-off fees for the customers?
11. Are these fees too high?
12. Are these fees covering the operational cost for each ASZ?
13. How can the ASZ be optimized in the view of economy and ecology?
14. In particular, can the number of ASZ be reduced at the same degree of service for the communities involved, and are savings arising from such a reduced amount of ASZ?

Society today faces many challenges regarding how to create systems for recycling that are acceptable for citizens, while also integrating considerations aspects such as efficiency, type and amount of the waste that is dropped off at each ASZ, employed methods, costs, etc. Thus, this study aimed to achieve maximizing the results by optimally assessing and categorizing the waste collection centers in order to exploit this treasure of information in view of transferring best practice in waste management to other parts of the world.
The following sections will give an overview of the present situation regarding the waste management in Austria, in Lower Austria, the association of municipalities for tax collection and environmental protection in the district of Mödling (GVA Mödling), and the current legal framework of the waste collection centers.

1.2. Waste Management in Austria

The waste management in Austria has been characterized by the increasing prominence of the involvement of different stakeholders including private and public companies. In Austria there are many similarities how waste management is being organized due to the common legal regulations among the federal provinces. For instance, public institutions dominate the municipal solid waste (MSW) management sector. Therefore, MSW is a public service and all municipalities are committed to collect the waste of every business and every household. Individuals are obliged to pay for this service. On the other hand, private companies play an important role in the Austrian municipal solid waste sector. The involvement and mutual dependence among private companies, consulting companies, and holding companies makes it difficult to understand the nature of the specific tasks of each stakeholder. For example, there are often alliances built between companies to have competitive advantages. These alliances can include collector/ collecting as well as recycling or disposal companies (Kleemann, 2010).

As regards with the waste collection in Austria, each municipality is responsible for the waste collection by charging a fee to every household or company. However, the private sector over the past years has increasingly taken a share in such a duty, which has led to the emergence of new partnerships among different stakeholders. The outsourcing of solid waste management became popular among some municipalities, resulting in new private disposal companies. The main reason behind the involvement of the private sector is to become more efficient and to reduce costs. Although one has to bear in mind that it is important to provide waste collection service at reasonable costs as well as to avoid the disadvantages of areas that lack of infrastructure. Thus, it is optimal to always maintain a balanced involvement among different private and public institutions. In practice, municipalities assign different collection fractions such as paper, glass, metal or plastic to the private companies in order to keep a balance (Kleemann, 2010).

According to the Waste Management Act of 2002, waste must to be recycled as long as it is ecologically advantageous, technically possible and additional costs are not disproportional compared to other waste treatment methods. Also, it highlights the importance of the establishment of a market that produce secondary raw material (Österreichisches Bundeskanzleramt, 2002). For this matter, recycling aims to obtain secondary raw material from recyclates, or it also describes the use of incineration gained from burning material with a high calorific value. For instance, recycling paper will induce of the production of recycled paper. Another example would be that glass would replace primary raw material in the packaging industry and so on with plastic. As there are many different types of existing plastic, material recycling is sometimes difficult to carry out and therefore, incineration use is commonly in practice (Kleemann, 2010).

As for treatment and disposal it must be noted that there have been major effects after the entry into force of the Landfill Ordinance in 1996. The new Landfill Ordinance seems from the figures that the landfill tax has first of all given incentive to incinerate municipal solid waste. Austria has an incineration tax - EUR 7/ t before 2012 and EUR 8/ t from 2012) - much lower than the tax on landfilling (Fischer et al., 2012). Furthermore, the landfill tax, together with the Landfill Ordinance, has encouraged recycling and recovery of waste. Both measures led to reduce quantities of waste going to landfill. According to the Austrian Federal Environment Agency this effect is demonstrated since the amount of landfilled waste from households and similar establishments was reduced by about 34 % from 2004 to 2009; the total amount of landfilled waste dropped by 28 % from 2003 to 2010; the revenues declined by about 50 % in recent years (despite higher landfill rates) (Fischer et al., 2012). In addition, there are strict regulations that have to be fulfilled concerning technical and geographical requirements of landfills. At the moment there is enough space available on Austrian landfills and no requests for developing new sites have been made (Herczeg, 2013).

The collection, treatment and disposal of MSW are mostly financed through the waste collection fees paid by the households and companies. Households pay to the municipality that is responsible for the service. Companies can also contract private waste disposal businesses. A study conducted by the Federal Chamber of Wage- and Salary-earners ("Bundeskammer für Arbeiter und Angestellte") demonstrated that waste collection fees varied between +/- 40% to +/- 70% for the same service (Arbeiterkammer Österreich, 2005). The main factors influencing the costs for waste treatment and disposal and therefore the waste collection fees are the service level (emptying frequency, collection or bring system, etc.) and the structure of the catchment area (topography, population density, etc.). The organizational structure such as the involvement of private companies and the cooperation with associations also influences the costs. The involvement of the private sector does not necessarily lead to lower costs at the same quality level. However, the cooperation and exchange with other stakeholders can be beneficiary and reduce costs. The consideration of existing structures and the involvement of available facilities and free capacities lead usually to lower waste disposal fees (Kleemann, 2010).

1.2.1. Altstoff Recycling Austria (ARA)

An important player on the Austrian recycling market is the "Altstoff Recycling Austria AG" (ARA), which was founded based on an initiative of the Austrian economy, so as to take on the responsibilities of many waste companies. ARA is the central contact point of the economy for questions of packaging, waste collection and recycling. As a non-profit company it strives to work performance-oriented, cost-efficient and ecologically feasible. The companies that fall within the packaging act pay licenses for all packaging material they use for their goods, with the amount based on the material (paper, glass, plastic). ARA uses the revenues from license fees to organize and finance the collection, recycling, sorting and recovery of the packaging waste in Austria. Currently the ARA-system consists of 8 economically distinct sub-companies based on branches. On October 1st 2008 all sub-companies of ARA were merged into the ARA AG, with the exception of the "Glasgesellschaft AGR GmbH" that continues to be distinct by law but is still an important part of the ARA system (Figure 1) (ARA, n.d.).

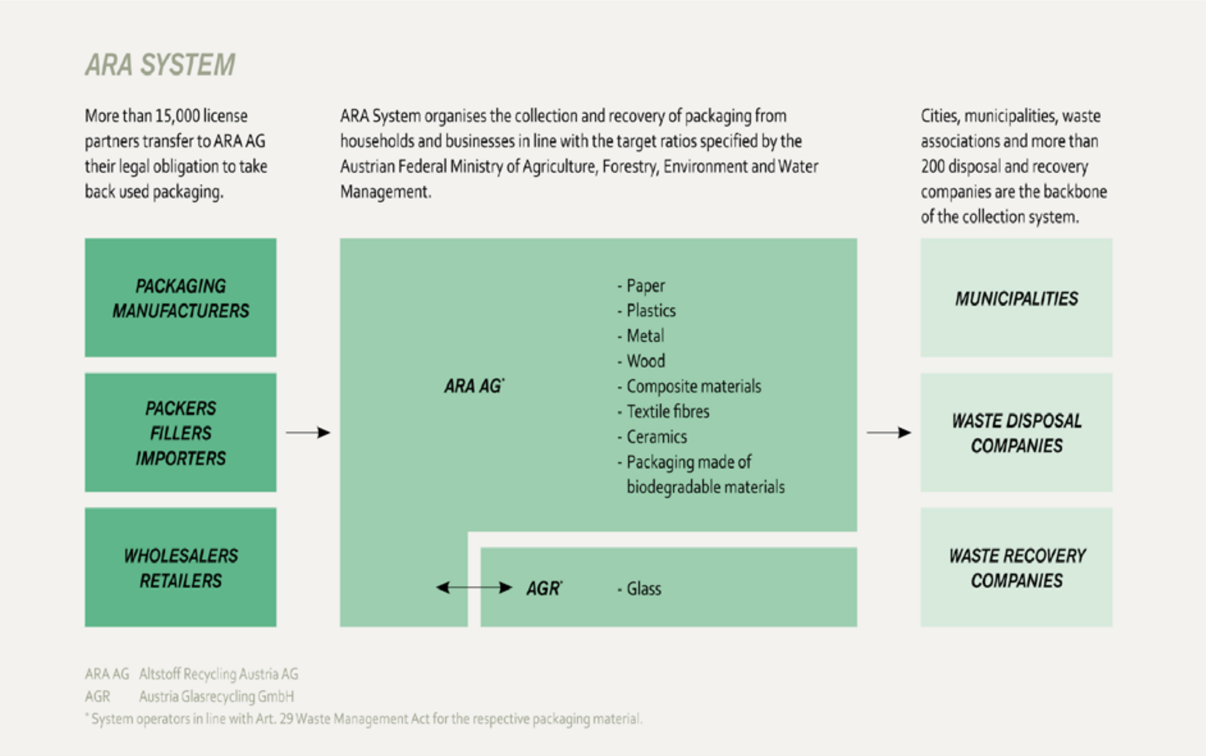

Figure 1. – ARA System (ARA, n.d.).

1.3. Waste Management in Lower Austria

The example of Lower Austria was chosen, as a similar situation can be found in nearly all other federal states. Vienna and Burgenland are the exceptions since they both are separately managed. In Burgenland waste management is centrally organized and all municipalities are members of one statewide association, which sets fees and is, together with a subsidiary, responsible for all stages of waste management. In Lower Austria waste associations are organized within districts or municipalities (Kleemann, 2010).

The “Lower Austrian Waste Management Association” (NÖ AWV) builds the umbrella corporation of waste management in Lower Austria, in cooperation with the department of “Environmental Economy and Regional Planning Support of the State of Lower Austria” (RU3). The Lower Austrian management organization is composed of 22 waste management associations and 3 urban units integrating 555 communities out of a total of 573 (Figure 2) (Amt der NÖ Landesregierung, 2013).

The “Niederösterreichische Beteiligungsgesellschaft für Abwallwirtschaft und Umweltschutz GesmbH” (NÖ BAWU GesmbH) was founded in 1996 (GVU Melk, n.d.). Its members are most of the Lower Austrian waste associations, the statuary city Krems/Donau and the composting treatment plant in St. Pölten (Der Rechnungshof, 2010). The inspection and evaluation of all appropriate disposal and utilization measures - especially of residual and bulky waste - is the most important goal. Parts of this are the implementation of ecological and economical feasible transport logistics, management of quantitative and calorific values, and the appropriate measures for disposal of old cooking oils/fats (NÖLI) as well as processing of the electronic goods collection (Amt der NÖ Landesregierung, 2013).

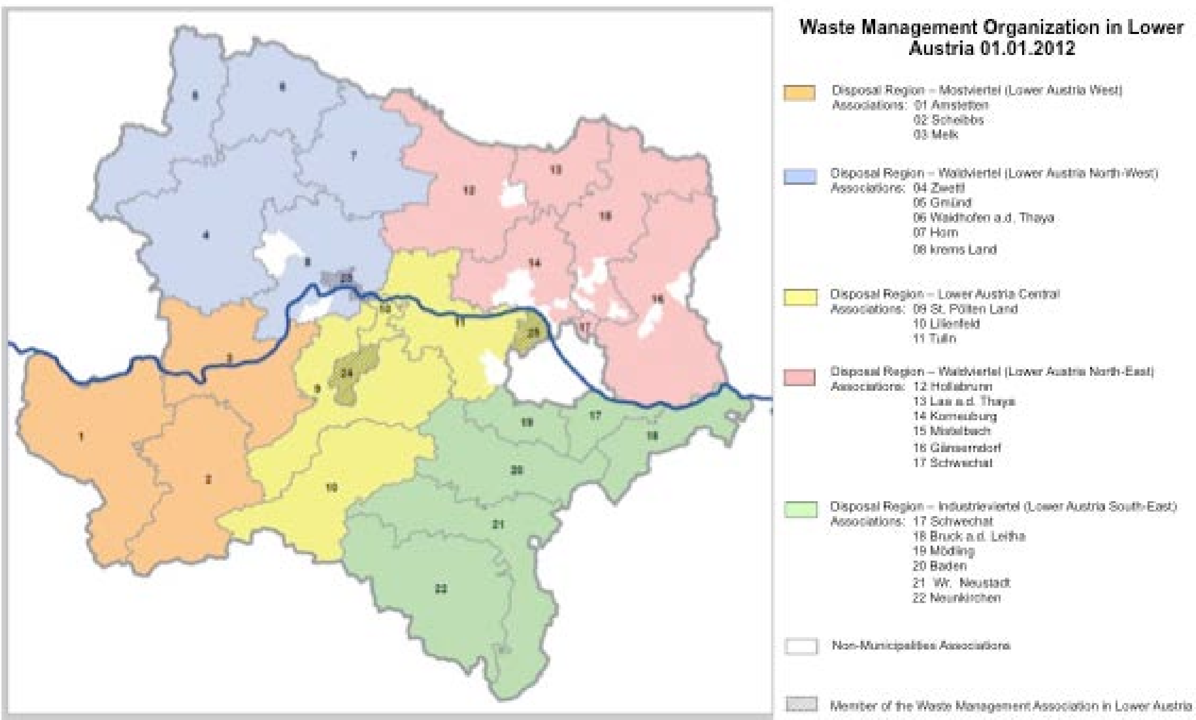

Figure 2. – Waste management organization in Lower Austria, disposal areas, associations, and non-municipalities associations (“Nichtverbandsgemeinden“). Adapted from (Amt der NÖ Landesregierung, 2013).

In addition, the communal collection systems can be distinguished between on-site collection systems (collection directly where waste occurs) and at-site disposal systems (waste is collected in specific places). These two terms are also defined under the § 3 NÖ AWG of

1992 (NÖ Landtag, 1992). According to the legal text “At-Site Disposal System” is an acquisition form where the waste is either deposited by their owners in marked containers and a marked area, or given to a local department on specific dates. Whereas “On-Site Collection System” is an acquisition form where the waste is deposited in marked containers inside the property of the respective owner and made readily to be picked up on specific dates. The designated waste separation has to be observed by the owners (NÖ Landtag, 1992).

Moreover the waste for every community is collected in the ASZ. Every community has to install ASZ close to households and in appropriate sizes in order to collect the waste material (glass, packaging material, textiles, sometimes paper). In the past couple years the density and the extension of the existing waste collection centers in Lower Austria has been promoted for the disposal of bulky waste, problematic waste, green waste, construction waste and others (Figure 3). In the present there are 436 waste collection centers and 9.683 waste gathering islands. In 415 communities at least one waste material collection center is readily available (Amt der NÖ Landesregierung, 2009).

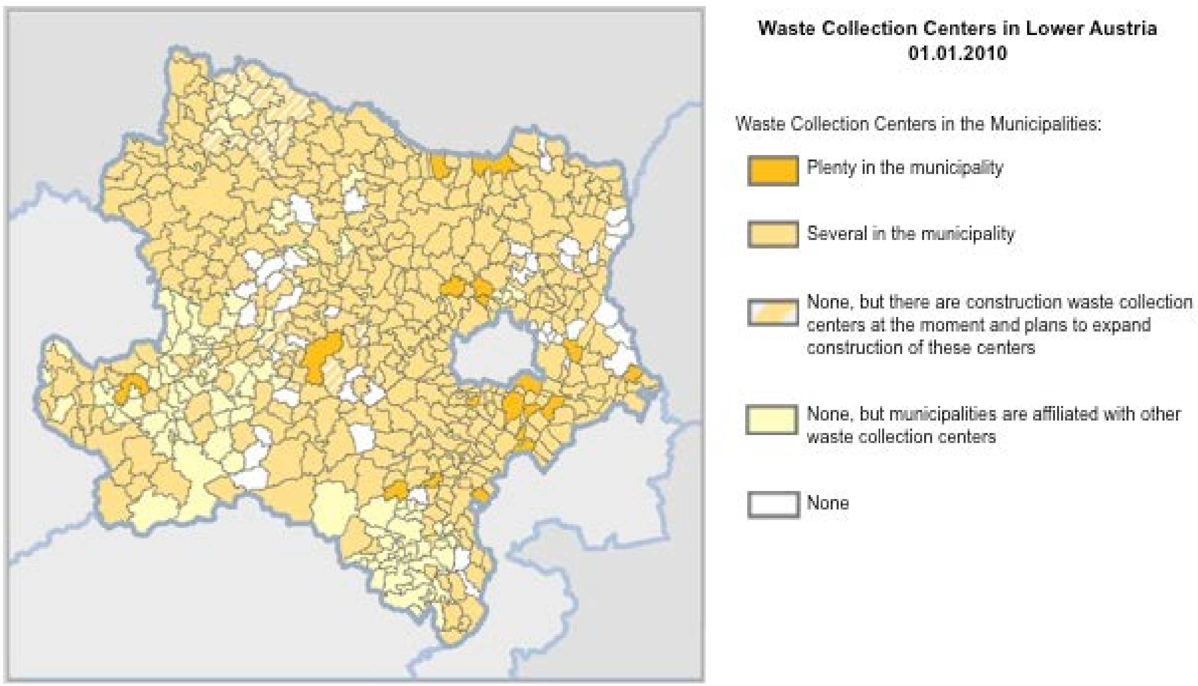

Figure 3. – Density of the ASZ in Lower Austria adapted from (Amt der NÖ Landesregierung, 2009).

It is important to note that due to the significant growth of structures, different utilization systems and different agreements/ contracts with waste disposal and recycling companies a set of different waste separation systems have been established in Lower Austria. Each waste association is responsible for setting a system of waste separation, for separating the different waste for collection (on-site collection or at-site disposal system) and for providing the financing of this waste economy as cost-efficient as possible (Amt der NÖ Landesregierung, 2009).

Another important aspect of the waste management system in Lower Austria is the collection system for the industries. The entry into force of the packaging act in 1993 requires all producers, distributers and importers to take back all of their marketed packaging material free of charge and to reuse, reutilize or recycle them. The fundamental idea behind the packaging act within the terms of the waste management law is to aim for a substantial reduction and prevention of unnecessary packaging (Österreichischer Nationalrat-Umweltausschuss, n.d.).

1.3.1. GVA Mödling

The district of Mödling was chosen as an example of suburban municipal waste management. The district is located in Lower Austria in the "Industrieviertel" (industrial area) immediately adjacent to the south of Vienna. It is divided by the thermal line, which is situated in the eastern half of the Vienna Basin and the western of the Viennese Woods (Figure 4) (Amt der NÖ Landesregierung, 2007) (Wikipedia, n.d.).

Figure 4. – Geographical location of the district of Mödling (Amt der NÖ Landesregierung, 2013).

The district of Mödling with a population of 114.825 inhabitants living in 51.066 households is geographically one of the smallest. However, it is considered economically to be one of the strongest in Austria. This is because of its high tax revenues (Amt der NÖ Landesregierung n.d.a). The district is divided into 20 municipalities including a city and 12 market towns (Figure 5) (Wikipedia, n.d.).

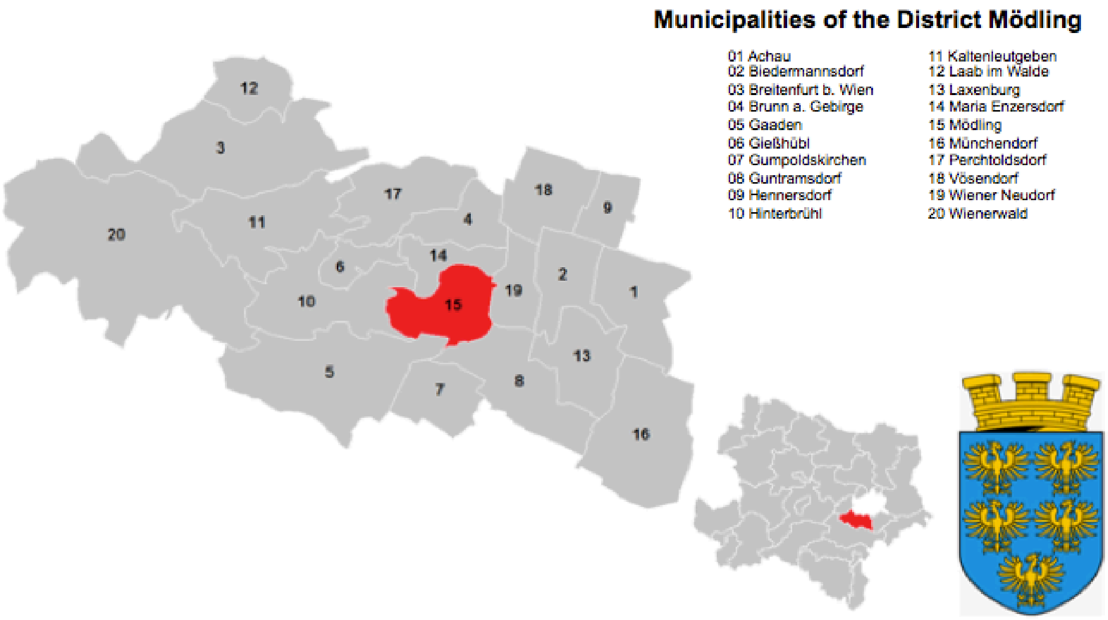

Figure 5. –Municipalities of the district Mödling adapted from (Wikipedia, n.d.).

The GVA Mödling aims to promote sustainable consumption of resources and management of waste through prevention at source, reuse and recycling. In addition, the GVA Mödling collection system is mainly based on waste disposal at ASZ at any local municipality (Figure 6) (GVA Mödling, n.d.a).

Figure 6. – Waste collection center (GVA Mödling, n.d.a).

Beside the curbside collection, it is possible to dispose, among others, the following waste fractions at ASZ:

- **Waste wood**: Waste wood typically includes items such as tables, beds, chests, chairs, doors, fruit crates, pallets etc. Theses materials are then shredded into wood chips and either incinerated or used for the production of pressboard.

- **Tree and shrub cuttings**: Tree and shrub cuttings are usually extremely bulky to collect in compost bins. The waste material is used in composting plants as a structural material for aeration of compost piles.

- **Demolition and construction waste**: Construction waste includes items such as bricks, concrete/cement, floor tile, gravel, stones, etc. Construction waste is generally separated in recycling facilities (gravel, sand) and is then recycled. Unusable fractions are deposited in construction waste landfills. These waste materials do not include construction waste such as installation or insulation materials, plastics, etc. It is important to note that wood and iron may be present only in small amounts at any ASZ.

- **Cardboard waste**: Small cardboard boxes can also be disposed in any wastepaper bin. In addition, larger boxes are collected as well in the waste collection centers and they will be brought back to the in the paper industry for the production of cardboard.

- **Styrofoam**: Styrofoam is foamed plastic, which is used mainly as packaging. Polystyrene parts are granulated and they can be used in the construction industry (as for thermal insulation of houses, screed, insulation debris). In larger quantities or bulky polystyrene parts will be accepted at any ASZ if they do not fit into the yellow bin.

- **Car tires**: Old car tires are shredded and they are used thermally in the cement industry. The contained sulfur in the tires is included in the cement

- **Old/Used textiles**: Old/used textiles are collected clean. These are items such as women's, men's and children's clothing, shoes, table, bed and household linen. The collected waste is sorted into good quality - “wearable” - clothing, rags and regeneration material. The clothing will be brought to markets in order to be sold in thrift stores, in Eastern Europe and in developing countries. Cleaning cloths and rags are shipped particularly in the industrial sector where from the unusable residue (regeneration material) will be recovered wool in small pieces. Moreover containers for clean and “wearable” clothing and shoes are available at any waste collection center.

- **Dead animals**: In some ASZ, the disposal of animal carcasses can be done free of charge. The disposal of animal carcasses can be found in the district of Mödling in the following communities: Breitenfurt b. Wien, Hinterbrühl, Kaltenleutgeben, Mödling, Perchtoldsdorf and Vösendorf. The animal carcasses are collected in refrigerated containers under the following conditions:

    - Dead animals (dead domestic animals in very small quantities)
    - Animal waste from households (in small quantities)
    - Dead wild animal body, the removal of carcasses is particularly a matter of the public interest
    - In Lower Austria, dead pets (dogs, cats, rabbits, etc.) may also be buried on private land.

Furthermore, hazardous waste, oil-cooking waste, electronic waste, bulky waste can be also disposed at ASZ in the district of Mödling (GVA Mödling, n.d.a).

1.4. Legal Framework for Waste Collection Centers

This section intends to give an overview of the current legal framework with regards to waste collection centers. The present legal framework for ASZ is very limited and few laws have been adopted within the Austrian waste management legislation. The Austrian waste management legislation has a complex legal nature with responsibilities shared among the nation, the federal states and the municipalities. The storage, collection and disposal of municipal waste are primarily within the jurisdiction of municipalities and are largely governed by municipal laws, which determine the legal and administrative arrangements for collection and disposal. The main legal basis for waste management in Austria is the federal law for sustainable MSW management (Österreichisches Bundeskanzleramt, 2002). This Act stipulates, first, how to handle the waste that has been generated. Secondly, it defines requirements that serve to prevent the generation of waste, while establishing the duties of the persons subject to the Act. (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2011).

The term “waste management” within the meaning of the Austrian Constitutional Act (B-VG) includes all measures for the prevention, reduction, recovery, safe treatment and disposal of waste. Under constitutional law, the federal government has the authority to issue and enforce legislation governing hazardous waste (cf. sec. 10 (1) (12) of the Federal Constitutional Act.). With the adoption of the Waste Management Act of 2002, Federal Law Gazette I No 102/2002, the federal government made extensive use of its authority, enacting uniform nationwide regulations governing hazardous and non-hazardous waste. The Austrian federal provinces have jurisdiction over municipal waste collection and the planning of disposal plants for non-hazardous waste (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2011).

In addition, the only regulation that gears directly to the ASZ under the Waste management Act of 2002 is described in section §54. This regulation sets publicly available waste material collection center points for hazardous materials as well as for municipal waste on a national level. Essentially, it requires a permit from the public authorities when establishing such centers considering that the ASZ may have an effect on the public’s interests. Such permit must be granted within three months, if not the “public interest” will be threatened. This permit can be revoked at any time if the activities at the centers do indeed represent any sort of threat. A different procedure applies for treatment facilities (§37 in conjunction with Annex 5 part 1). The establishment of such centers must follow certain conditions otherwise construction and operation is prohibited (Österreichisches Bundeskanzleramt, 2002).

Furthermore each municipality in the district of Mödling has responsibilities and duties that need to be fulfilled for waste collection centers under the Lower Austrian Waste Management Act of 1992 (NÖ AWG 1992). Section §11 indicates that each municipality is held responsible for attending to and caring for the facility, and the operation of a waste collection center according to the provisions in this law/ statue. It also states that each municipality has the obligation to provide and maintain trash/ garbage bins. It is the responsibility of the owner or the beneficial owner to maintain the bins locked and the surrounding area clean (NÖ Landtag, 1992).

Moreover this section (§11) further indicates that waste can be collected according to an on-site collection system or at-site disposal system, whereby the disposal system should be reserved for waste with a recycling, reuse or recovery purpose. The provided bins should be used. Also, if the waste is collected on-site, the property-owners in the mandatory area are responsible for arranging the delivery or pick-up of the bins. The bins are to be mounted or arranged in such a way that they remain accessible to the customers even during bad weather conditions. The bins should not constitute an undue nuisance for (house) residents or the neighborhood. If the property owner does not meet these obligations, the municipality should decide upon the arrangement and demount the bins by means of a notification (NÖ Landtag, 1992).

The waste is collected by at-site disposal, the municipality needs to arrange and mount trash bins. In addition, quantity and size of the bins to be mounted according to the on-site collection is to be identified via notification in a way to ensure that the empirically accumulating waste is collected (§ 9). Also it can be collected within the collection period according to the state of the art technology. In the case of bags being used, the quantity of bags needed is to be determined in the notification as well. Respectively, beneficial owners of properties without residential buildings are exempted from the obligation to use the waste bins (§ 3), if they can substantiate a collection and treatment of their waste appropriate to the goals and principles set out in § 1. Following a written request, the exemption is to be issued by the municipality in form of a notification including the terms and obligations of the exemption. (NÖ Landtag, 1992).

There are other pieces of regulations, which are also extremely important. For instance, under the Lower Austrian Waste Management Plan - a strategic plan, which is updated every 5 years and based essentially on the Lower Austrian Management Act of 1992 - there are measures specifically related to the ASZ. These measures describe the minimization for recycling material in waste residual by optimizing the separate collection of waste and its recovery. Also, it sets a collection efficiency rate of 80% for recycling material (except packing plastic) as well as it aims at expanding the offers of ASZ, preferring smaller regional projects/ solutions for several neighboring municipalities. Likewise, it sets an achievement rate for the remaining waste materials and especially for paper an absolute decrease has been registered out of all the residual waste according to the residual waste analysis of 2005/ 2006 (Amt der NÖ Landesregierung, n.d.b).

In addition to these regulations there are common minimum standards for ASZ in Lower Austria for which each waste association needs to agree to and apply them. These guidelines and standards also help to specify or introduce the state of the art in ASZ with regard to the operating modes. Among these minimum standards it should be emphasized that for bulky waste (private households) any ASZ should provide free of charge disposal and a home pick-up service on a regular annual basis. Further, for waste in general, each ASZ should at least offer the possibility to dispose fractions such as bulky waste, wood, iron, NÖLI, e-waste, green waste and cardboard. Furthermore, these minimum standards set recommendations for opening hours and area-coverage with a minimum of one collection center per 10.000 inhabitants, except in urban regions with respective capacities potential. If a collection center fails to comply with the requirements, it is not considered to be a (waste) collection center as laid down in the minimum standards. The area-coverage thus needs to be achieved by other means. (Die NÖ Umweltverbände, 2009).

The legal framework aspires to highlight the important role in the overall performance in municipal solid waste recycling in Austria. The Austrian legal framework should be taken into consideration since its municipal solid waste management remains consistently at a high level in Europe (Herczeg, 2013).

1.4.1. Opening Hours

The recommended opening hours are defined in the ASZ guidelines (Amt der NÖ Landesregierung, 2009) and in the minimum standards (Die NÖ Umweltverbände, 2009) and they are based on the number of inhabitants in each municipality and primarily oriented to the residents' needs.

According to the ASZ guidelines (table 1), the opening hours should enable regular use of the waste collection centers. They were set to be generous and customer-friendly oriented. In particular they were determined according to the working population since it has limited time for waste disposal in ASZ during its working hours. This particularly applies for commuters. It is thus required that the ASZ are also open outside the main working hours that are considered to be from Monday to Thursday 8 a.m. - 5 p.m. and Friday 8.am - 12 p.m. In order to achieve a degree of efficiency with regard to time availability of the ASZ, it was therefore established that each ASZ should open at least once a week.

Table 1. – Recommended opening hours according to ASZ guidelines (Amt der NÖ Landesregierung, 2009).

Size Categories	**Inhabitants per Municipality**	**Total Hours per Week**	**Hours Outside Working Hours**
Small	1.000 – 2.000	2-4	1-2
Medium	2.000 – 5.000	4-8	2-4
Large	5.000 – 10.000	8-20	4

The opening hours should be determined in accordance with the working population and they should be duly published (municipal newspapers, informative fliers) with the relevant information of the type of waste that can be collected.

In addition, to ensure continued effective operation of the ASZ due to any possible unexpected illnesses, emergencies, or extenuating circumstances; it is important that the ASZ have extra qualified/ instructed personnel ready to fulfill their tasks (Amt der NÖ Landesregierung, 2009).

On the other hand, the minimum standards also set opening hours, which are established based on the number of users with primary residence in a particular municipality. Table 2 shows a summary of the recommended opening hours according to the minimum standards in Lower Austria.

Table 2. – Recommended opening hours for ASZ according to minimum standards (Die NÖ Umweltverbände, 2009).

Inhabitants per Municipality	**Open to Users**	**Opening Hours during Working Hours**	**Opening Hours Outside Working Hours**
0 – 1.500	twice a month	2	1
1.501 - 3.000	twice a month	3	2
3.001 - 5.000	twice a month	4	3
5.000 - 10.000	once a week	4	5
10.001	once a week	8	10

1.5. Efficiency and Effectiveness

The concepts of effectiveness and efficiency are similar terms and they describe the performance of any industrial system. Both concepts are to technology or economics in principle clear, straightforward and fundamental. The distinction is important, Effectiveness means, “having an effect”, whereas the implication in efficiency is doing so with the minimum of effort needed to achieve the effect. Thus, the relationship between effectiveness and efficiency seems dependent on the goal structure established, or not established. If there is a main goal established, effectiveness may be defined as reaching that goal. Efficiency may be defined as reaching this goal, without wasting resources, estimated on the basis of what is socially and technically possible (Emmelin, n.d.). Furthermore, the efficiency according to Slack N. (as cited in Sundina et al., 2011) is thus often measured in production systems as „actual output / effective capacity“. However, improving efficiency makes only sense when it is tied to cost reduction. There are two ways to increase efficiency according to Ohno (as cited in Sundina et al., 2011): by increasing production quantity and/ or by reducing the costs (Sundina et al., 2011).

However, these concepts must be redefined in the field area. A more efficient redirection of the existing sources of financing and the expectation of the waste collection centers to provide greater service/ value for money represent the reality of the majority of the ASZ. A waste collection center is thus efficient when it attains the maximum level of results for a minimum level of investment. The investments and results in this context must be evaluated, aggregated, measured, and marked. Likewise, an effective ASZ expects to accomplish an acceptable level of the desired outcomes, which must/ may be realized (Emmelin, n.d.).

In addition, any taxpayer/ individual would like to be informed of whether each ASZ are achieving positive results. Therefore, it must always be borne in mind not only the simple link between what is invested in the facilities and the results of each facility, but also other important determinants in leading the waste collection centers, such as collection methods, opening hours, accessibility, etc. This is why it is necessary to take care of the balance among the dimensions of efficiency and effectiveness in ensuring the well functioning of the ASZ.

2. Materials and Methods

For this study on-site inspections and interviews with an expert of the GVA Mödling (Tippel, 2014) and with stakeholders of the waste management association were made in order to better understand the functioning of the ASZ as well as to clarify uncertainties.

2.1. Waste Data Assessment and Processing

Waste collection data from 2013 was obtained from the GVA Mödling (GVA Mödling , 2013). The total amount of disposed waste was provided for each municipality/ ASZ and waste fraction in tons. Further, the amounts for different utilization routes of collected waste and the employed method(s) for collection of a specific fraction were also included in the data file. For the purpose of this study only waste fraction could be considered and analyzed that were exclusively collected at ASZ. Thus, lightweight packaging, used glass, styrofoam, "Ökobox", and metal (cans) that could also disposed outside from the ASZ (e.g. in containers on the street) were excluded. For these fractions no further discrimination regarding the site of disposal was made and the amount collected at the ASZ could not be determined.

Results are presented in absolute numbers for each fraction as well as in proportions for grouped fractions (waste groups). To assess a potential effect of the population size on the total amounts of disposed waste across municipalities, data was additionally adjusted to kg waste per inhabitant. Population data was provided from the year of 2013 from a public available website (Amt der NÖ Landesregierung, n.d.c).

2.2. Material Flow Analysis

The MFA is a systematic assessment of the flows and stocks of material within a defined space and time. The results of the MFA can be controlled by simply comparing all inputs, stocks and outputs of a process, making it an attractive decision-support method tool in resource management (Brunner and Rechberger, 2004). According to Brunner, the MFA allows the comparison and exchange of waste management data in an impartial, transparent and reproducible way.

The MFA can be applied everywhere for waste management for any defined space and time boundary, from as small as a single treatment process plant within a day to as large as a nation within a year. Its applicability makes it easier to identify hidden problems and consequently develops a new whole waste management system of a locality or a municipality for instance. If the MFA points out weaknesses in a waste management system, changes can be made at one particular process, which may well improve the efficiency and the effectiveness of such a facility. This does not mean that this change is positive for the waste management system as such. It may also cause negative outcomes for other processes upstream or downstream the material flows. When such negative outcome overweighs the positive impacts, the proposed changed are not an effective strategy from a holistic point of view (Brunner and Tang, n.d.).

MFA provides a system approach that aims to help policy makers to formulate strategies that improve the overall performance of a goal-oriented waste management system (Brunner and Tang, n.d.). The implementation of a MFA in Mödling tried to foster understanding of the functioning of ASZ and will enable to represent the many ASZ in a systematic and uniform way.

2.2.1. Terms and Definitions

As developed by Baccini and Brunner in the 1980s, the MFA uses fundamental key terms and procedures, which are listed below:

- **Material**: The term material includes both, substances and goods. Substances are defined as any (chemical) element or compound composed of uniform units. Good represents a substance or a mixture of substances that has an economic entity with a positive or negative value.

- **Process:** A process can be defined as the transformation, transport, or storage of materials. This can be either examined as a closed system or black box, meaning that only inputs and outputs are of interest and not the details within the box. If the process is of extreme importance or interest, the process must be divided into two or more subprocesses. Processes are linked together by flows and fluxes.

- **Flow and Fluxes:** Flow is defined as the rate of flow mass through a conductor and a flux is defined as the flow per cross section.

- **Transfer Coefficients (TC):** Transfer coefficients describe the partitioning of a substance within a process and are defined for each output good of a process. These are multiplied by 100, giving the percentage of the total throughput of a substance that is transferred to a specific output good (also known as partitioning). Moreover transfer coefficients are not necessarily constant and are technology-specific values that depend on the characteristics of a process.

- **System and System Boundary:** The system is the object that is investigated by an MFA. This is defined by a group of elements, the interaction between these elements, and the boundaries between these and other elements in space and time. The temporal boundary depends on the kind of system inspected and the given problem. It is the time span over which the system is investigated and balanced. The spatial system boundary is generally fixed by the geographical area in which the processes are located. This can also be an abstract area. This can be the premise of a company, a town or city, region, country, the whole planet or even a virtual limit such as a waste-management system of a county (Brunner and Rechberger, 2003).

In addition, STAN (short for subSTance flow ANalysis) is software that has been developed in order to support MFA. This free software provides a selection of graphical representation of material flows, processes and system boundary. STAN allows the input of data about mass flows, substance concentrations and transfer coefficients. Users can model flow and stock on both level of goods and substances, constituting the basis for assessing resource conservation and environmental protection, the two basic goals of waste management. The use of transfer coefficients (or partitioning) determined by technological factors is particularly convenient for calculation process output flows by STAN. The software has a unique feature based on mass balance principle – inputs must match outputs (Brunner and Tang, n.d.).

Therefore, if waste generation rates are known, the total amount of waste that flows and leaves a system by recycling, landfilling or incineration is also determined. This means that no mass can disappear and the differences among these inputs and outputs may carry out further investigations (Brunner and Tang, n.d.).

2.2.2. Description of the Study

System boundary: This study analyzes all the municipalities of the GVA Mödling. The district of Mödling serves as an example of suburban municipal waste management area. In addition, the establishment of a system boundary came about of the necessity of this study to recognize and identify the relevant waste management data as well as collected quantities so as to have them in a consistent and comparable manner to all members of the waste management associations. This enables that uncertainties can be reduced in data collection.

Most importantly, these uncertainties can clearly state relevant remarks/ results, which can explain operational activities in the study area.

Temporal boundary: The temporal boundary was taken for the year 2013.

Flow: Waste groups in tons in 2013

Goods: Waste groups (for example: biogenic or construction waste)

Processes: Storage of the goods

Assumptions: The GVA Mödling transfers all the different waste groups from the ASZ to authorized waste collection services or waste treatment operators. For some waste groups, it is unknown in detail whether the waste is energetically or materially recycled, incinerated or landfilled. Thus, assumptions had to be made that were based on recommendations of the GVA Mödling (Tippel, 2014). Table 3 shows the (assumed) proportions for the different treatment methods of each waste group and waste fraction.

Table 3. – Proportions of the different treatment methods for the waste groups according to EDM data (GVA Mödling , 2013). * indicates assumptions. Bulky waste (BW), Biogenic waste (BioW), Scraps waste (SW), Excavation/construction waste (E/CW), Hazardous waste (HW), Waste electrical & electronic equipment (WEEE).

		Treatment Method						
Waste Group	**Waste Fraction**	**Incineration**	**Composting**	**Material recycling**	**Refinery**	**Landfill**	**Shredding**	**EAG processing**
BW		100%						
BioW	Garden/green waste		100%					
	Wood (trees and bushes)	50%*	50%*					
SW	Cardboard			100%				
	Scrap metal						100%	
	Used textiles			100%				
	Edible oils/fats				100%			
	Waste wood	50%*		50%*				
	Old tires	50%*		50%*				
E/CW	Construction waste					100%		
	Excavation waste			50%*		50%*		
	Baumix			50%*		50%*		
	Street-sweepings			50%*		50%*		
HW		80%*		20%*				
	Asbestos					100%		
WEEE								100%

2.3. Extra Drop-off Fees

In the district of Mödling, inhabitants pay waste management fees that allow them to use their respective ASZ in their home municipality, which they are registered. Therefore, and considering the waste management levies, waste can generally be disposed without any extra charge at the ASZ. Extra fees may only apply to amounts bigger than one household unit. In addition, the GVA Mödling has previously introduced a uniform charging scheme for some waste fractions that has already been implemented in some municipalities and calculation of drop-off fees for this thesis was based on this recommendation (Figure 20, appendix).

In table 4 extra charges, volume and density for different waste fractions are shown. Disposed units were determined from EDM data of the GVA Mödling by converting them into m^3 using the specific density of these waste fractions (table 4). It was assumed that each household at least disposed one unit of waste at the ASZ. Thus, extra drop-off fees were only incorporated when the calculated units were higher than the actual number of households in the respective municipality, which was based on latest available data of 2011 (Amt der NÖ Landesregierung, n.d.c). Disposal costs for asbestos were assessed similarly but without considering the number of households since every unit disposed had to be paid.

Table 4. – Recommended extra charges (based on figure 20, appendix), volume and density of different waste fractions. [1] (Berliner Stadtreinigungsbetriebe , 2013), [2] (Gutjahr and Rau, 2013), [3] (Schuttkarl, n.d.a), [4] (Schuttkarl, n.d.b), [5] (Schuttkarl, n.d.c).

One Household Unit = 2 m^3		
Waste fraction	**Price (€)**	**Density (ton/m^3)**
Wood	12	0.14[1]
Garden/ green waste	16	0.3[2]
Bulky waste	25	0.2[3]
One Small Unit = 0.5 m^3		
Waste fraction	**Price (€)**	**Density (ton/m^3)**
Construction waste	15	1.3[4]
Asbestos	25	0.7[5]

<u>Formula 1: Calculation of drop-off fees (wood, bulky waste, construction waste):</u>

$$\textbf{fee [€]}=\left(\text{households-}\frac{\text{waste [tons]}}{\text{density }\left[\frac{\text{tons}}{\text{m3}}\right]\text{*waste per unit[m3]}}\right)\text{*price per unit [€]}$$

If the calculated fee is a negative number, no additional disposal fees apply (€ 0.-)

Formula 2: Calculation of drop-off fees (asbestos):

$$\textbf{fee [€]} = \frac{\text{waste [tons]}}{\text{density } \left[\frac{\text{tons}}{\text{m3}}\right] \text{*waste per unit[m3]}} \text{*price per unit [€]}$$

For old tires, € 1 per car tire without rim, € 2.5 per car tire with rim and € 15 per tractor tire, respectively, were suggested from the GVA Mödling to be charged. It was assumed that 70% of this waste fraction originated from tires without rim and each a 15% from tires with rim or tractor tires. Calculation of the numbers of tires disposed and hereinafter the arising costs for ASZ users was based on the assumption that the weight of a tire without rim is approximately 8.5 kg (Continental Reifen Österreich, 2012), 20 kg with rim (Auto Motor und Sport, n.d.) and 54 kg for a tractor tire (kreissler24, n.d.).

Formula 3: Calculation of drop-off fees (old tires):

$$\textbf{fee [€]} = \frac{\text{waste [kg]}}{\text{weight per tire [kg]}} \text{*price per tire [€]}$$

2.4. Approach of ASZ Optimization

In order to assess whether the present situation (status quo) works efficiently and in an appropriate economic way two scenarios have been introduced with a reduction of the number of ASZ to three (scenario 1) and 14 ASZ (scenario 2), respectively. These two simulations were compared with the existing system of ASZ regarding their impact on ecological indicators (fuel consumption and carbon dioxide [CO_2] emissions), convenience for the district´s residents (distance to the ASZ, opening hours, fuel costs) and the effect on economic factors (investment and operational costs).

2.4.1. Geographical Distribution

Initially and to outline the current distribution of the ASZ across the district their geographical location was evaluated by assessment of geographic information system (GIS) data using an appropriate web application ("NÖ Atlas") provided by the state of Lower Austria (Amt der NÖ Landesregierung, 2014). A search in Google maps (Google, n.d.) with the postal address of each ASZ that were obtained from the GVA Mödling (GVA Mödling, n.d.a) was performed, to assess longitude and altitude (table 21, appendix) to exactly locate the ASZ on the map of the GIS application.

Subsequently, the inhabited area (excluding commercial or industrial regions) of each municipality was visually identified and marked on the map. For estimation of the approximate maximum linear distances between the corresponding ASZ and the resident´s homes, the linear distance between the ASZ and the north-eastern (NE), south-eastern (SE), south-western (SW) and north-western (NW) boundary of the inhabited area was measured and indicated on the GIS-map for further calculations and assessment of potential improvements.

2.4.2. Calculation of Distances, Fuel Consumption & CO_2 Emissions

Based on the assessment of maximal linear distances as described above (2.4.1) it was assumed for the status quo that (1) 25% each of the municipalities' population live along the marked distance from the ASZ to the NE, SE, SW and NW boundary, respectively, and that (2) residents are homogenously distributed between the ASZ and the boundaries along theses lines. Thus, half of the maximal linear distances were marked on the GIS map and considered for calculation of an overall mean average distance from these four distances of each municipality. Applying this method included and counteracted extremes such as users living very close to an ASZ and citizens located at the boundaries of the inhabited area. Further, calculation of annually travelled distances for both the status quo and the simulations (formula 4) include that each resident drop off its waste approximately four times a year, which has been revealed by observations of the GVA Mödling (Tippel, 2014).

Locations for hypothetical ASZ in the simulations were chosen to be at the geographical positions of current ASZ due to already existing infrastructure for waste disposal and thus a potential for cost reduction in adapting these centers. ASZ positions were considered in order to not exceed the maximum linear distance as assessed for the present situation. Scenario 1 evaluated an extreme situation with only 3 ASZ for the entire district (ASZ North = Breitenfurt b. Wien, ASZ South = Hinterbrühl and ASZ East = MUM, respectively). In scenario 2 the ASZ Gaaden, Guntramsdorf, Maria Enzersdorf, Perchtoldsdorf, Vösendorf, Wiener Neudorf, and Wienerwald were deleted. Unlike from the status quo where citizens are only allowed to use the ASZ of their home municipality (Tippel, 2014) it was assumed for both scenarios that residents may have access to any ASZ but only the nearest ASZ was considered for assessment of annually travelled distances and ecological indicators. To not change the assumption of the population´s distribution between simulations and present situation within each inhabited area, the distance from each simulated ASZ to the location of the previously (in status quo) identified half of the maximal linear distance in the NE, SE, SW and NW of each inhabited area was measured and the ASZ with the shortest distance was used for calculation of an overall mean average distance for each municipality. Based on the initial assumption that 25% each of a municipality's population live in the NE, SE, SW or NW of the inhabited area, the number of citizen was split into parts in the case that more than one ASZ was identified as the nearest for a certain municipality/ inhabited area (e.g. for municipality X, ASZ A is the nearest for residents in the NE, SE and SW but for citizens in the NW ASZ B is closer meaning that 75% of the population of municipality X use ASZ A and 25% ASZ B, respectively). An average diesel consumption of 6.8 l/100km and CO_2 emissions of 180 g/km were used for calculation of ecological indicators (formula 5 and 6, respectively) (Dekra, n.d.).

<u>Formula 4: Calculation of annually travelled distance:</u>

distance per year [km]=average distance [km]*citizens within the area of interest* visits per year [4]*round trip [2]

<u>Formula 5 and 6: Calculation of ecological indicators:</u>

$$\textbf{diesel per year [l]} = \frac{\text{distance per year [km]*6.8 [l]}}{\text{100 [km]}}$$

$$\textbf{CO}_\textbf{2}\textbf{ per year [kg]} = \frac{\text{distance per year [km]*180 } [\frac{g}{km}]}{1000\ [\frac{g}{kg}]}$$

2.4.3. Costs

2.4.3.1. Investment Costs

Investment cost calculation was based on data provided in the ASZ guidelines (Amt der NÖ Landesregierung, 2009) (table 5). Based on available data of inhabitant dependent investment costs a logarithmic trendline was computed using Microsoft Excel for Macintosh. The calculated formula (figure 7) was used to determine individual investment expenditures for each ASZ. For calculation of investment costs per inhabitant and year a depreciation period of 20 years was assumed (Amt der Steiermärkischen Landesregierung, 2004).

Table 5. – Investment costs according to ASZ guidelines (Amt der NÖ Landesregierung, 2009).

Size/ Categories	Inhabitants per Municipality	Investment Costs (€)	Area Required (m^2)
Small	1.000 – 2.000	66.000 - 176.000	approx. 400 - 600
Medium	2.000 – 5.000	176.000 - 286.000	approx. 600 - 1.200
Large	5.000 – 10.000	286.000 - 374.000	approx. 1.200 - 2.400

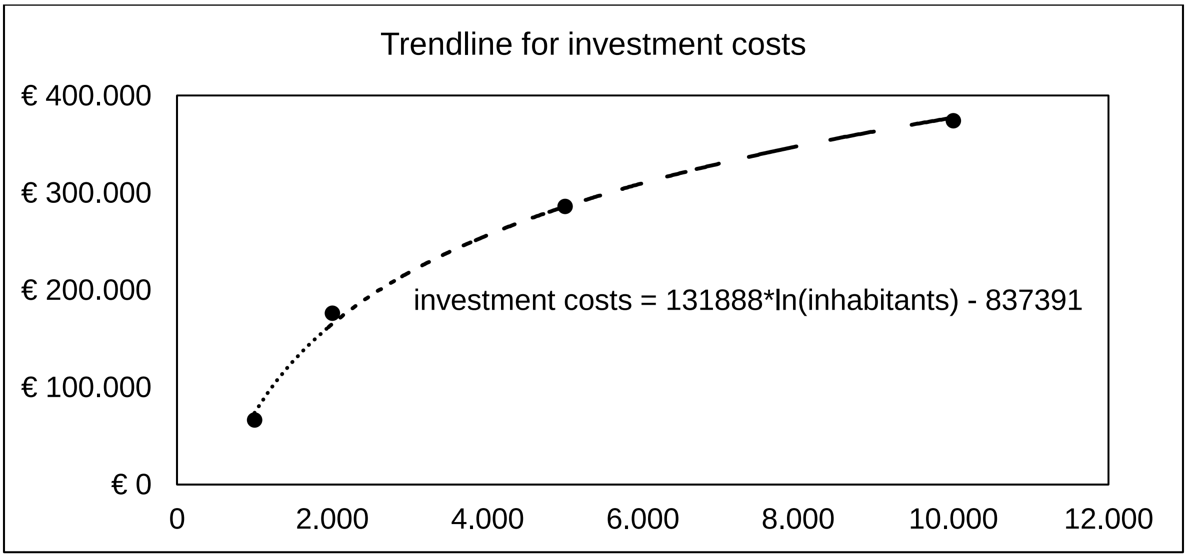

Figure 7. – Investment costs trendline calculated from data provided in the ASZ guidelines (Amt der NÖ Landesregierung, 2009).

2.4.3.2. Operational Costs

Operational costs, consisting of personnel and maintenance costs, were calculated dependent on ASZ opening hours. Thus, for the present situation annual opening hours for each ASZ were assessed according to the GVA Mödling (GVA Mödling, n.d.b). For both scenarios recommended opening hours per year for the simulated ASZ were derived according to the ASZ minimum standards (Die NÖ Umweltverbände, 2009) and not from the ASZ guidelines (Amt der NÖ Landesregierung, 2009) due to a more exact segmentation (users vs. opening hours) in the minimum standards (table 6). Subsequently operational costs were calculated for both the present situation and the scenarios using the recommended hourly rate of € 56.1 for personnel costs and € 20.5 for maintenance costs, respectively (Amt der NÖ Landesregierung, 2011).

Table 6. – Recommended opening hours for ASZ according to minimum standards; adapted from (Die NÖ Umweltverbände, 2009).

Inhabitants per Municipality	Minimum Opening Hours	Annual Opening Hours
0 – 1.500	2h twice a month	48h
1.501 - 3.000	3h twice a month	72h
3.001 - 5.000	4h twice a month	96h
5.000 - 10.000	4h once a week	208h
10.001	8h once a week	416h

2.4.3.3. Fuel Costs

Diesel costs for each municipality and per inhabitant were calculated from the total annual diesel consumption and assuming an average price of € 1.4 per liter diesel (formula 7) (ÖAMTC, n.d.).

<u>Formula 7: Calculation of diesel costs:</u>

diesel costs per year [€]=annual diesel consumption [L]*price per liter $[\frac{€}{L}]$

For assessment of costs per inhabitant fuel costs per year were divided by the inhabitants of the municipality of interest.

3. Results

3.1. Present Situation

3.1.1. Geographical Assessment of ASZ

In figure 8 (page 30) the geographical distribution of the ASZ across the district Mödling is presented. Table 7 summarizes the maximal linear distances within the inhabited area between ASZ and the boundaries in the NE, SE, SW and NW of the corresponding municipalities. Further, the geographical location within the respective inhabited area is shown.

In the entire district of Mödling in total 21 ASZ are provided and they appear to be inhomogenously allocated across the district's area (figure 8). However, a separate ASZ is supplied for each of the 20 municipalities with an additional ASZ in Guntramsdorf. The second ASZ (MUM) in this municipality is used both as a transfer station in cooperation with a national waste disposal company ("Saubermacher") and as a waste collection center for the entire district´s population, in particular for inhabitants of the municipality Mödling.

Most of the ASZ are not located in the municipalities' geographic centers as related to their boundaries but rather in the individual downtown area or close to it (figure 8). However, this does not apply for municipalities with a widely spread urban area and/ or no precisely defined downtown area (e.g. Gaaden, Guntramsdorf, Hinterbrühl, Kaltenleutgeben, Vösendorf, Wienerwald).

Maximal distances are largely dependent on the location of the ASZ within the inhabited area of the municipality territory and range from 0.1 km in Gaaden, Vösendorf, Biedermannsdorf and Wienerwald up to 7.8 km (Wienerwald), respectively.

Further, analysis of GIS data has revealed that in particular in the most inhabited region of the district - in the swath of Vösendorf/ Hennersdorf/ Brunn a. Gebirge/ Perchtoldsdorf in the north to Münchendorf/ Guntramsdorf/ Gumpoldskirchen in the south - two-thirds of all ASZ are located with partly nominal distances between ASZ (roughly 2.5 km linear distance) and even the two most distant ASZ (Perchtoldsdorf vs. Münchendorf) in this area are just 12.8 km apart.

Table 7. – Maximal linear distances between ASZ and the corresponding boundaries within each inhabited area and the geographical location of each ASZ (GVA Mödling, n.d.b) (Amt der NÖ Landesregierung 2014) (Google, n.d.). Distances for MUM were measured to the inhabited area of the municipality Mödling.

Municipality	**Linear distance (km) within inhabited area**				**Location**
	North-East	South-East	South-West	North-West	
Achau	0.9	0.8	0.9	0.8	Central
Biedermannsdorf	0.1	1.5	1.8	0.8	North-East
Breitenfurt b. Wien	1.7	1.3	6.8	4.2	North-East
Brunn a. Gebirge	1.0	1.3	3.4	1.4	East
Gaaden	0.1	1.6	2.5	2.0	North-East
Gießhübl	1.6	1.6	0.8	1.0	Central
Gumpoldskirchen	0.8	0.3	1.7	1.8	South-East
Guntramsdorf	2.6	0.1	2.1	3.2	South-East
Hennersdorf	0.5	1.1	0.6	0.5	Central
Hinterbrühl	5.1	3.3	1.2	1.4	South-West
Kaltenleutgeben	4.4	3.2	0.7	0.5	South-West
Laab im Walde	1.6	1.3	0.1	0.1	West
Laxenburg	0.7	0.7	2.2	1.5	North-East
Maria Enzersdorf	1.7	1.2	2.3	2.6	South
Mödling	1.2	1.1	3.1	2.0	East
Münchendorf	2.4	0.2	1.2	1.9	South-East
Perchtoldsdorf	1.6	0.3	3.9	2.7	South-East
Vösendorf	0.1	1.6	3.4	3.3	North-East
Wiener Neudorf	1.2	1.6	2.1	2.3	East
Wienerwald	1.7	0.4	6.4	7.8	South-East
MUM	2.7	0.8	1.7	4.6	South-East

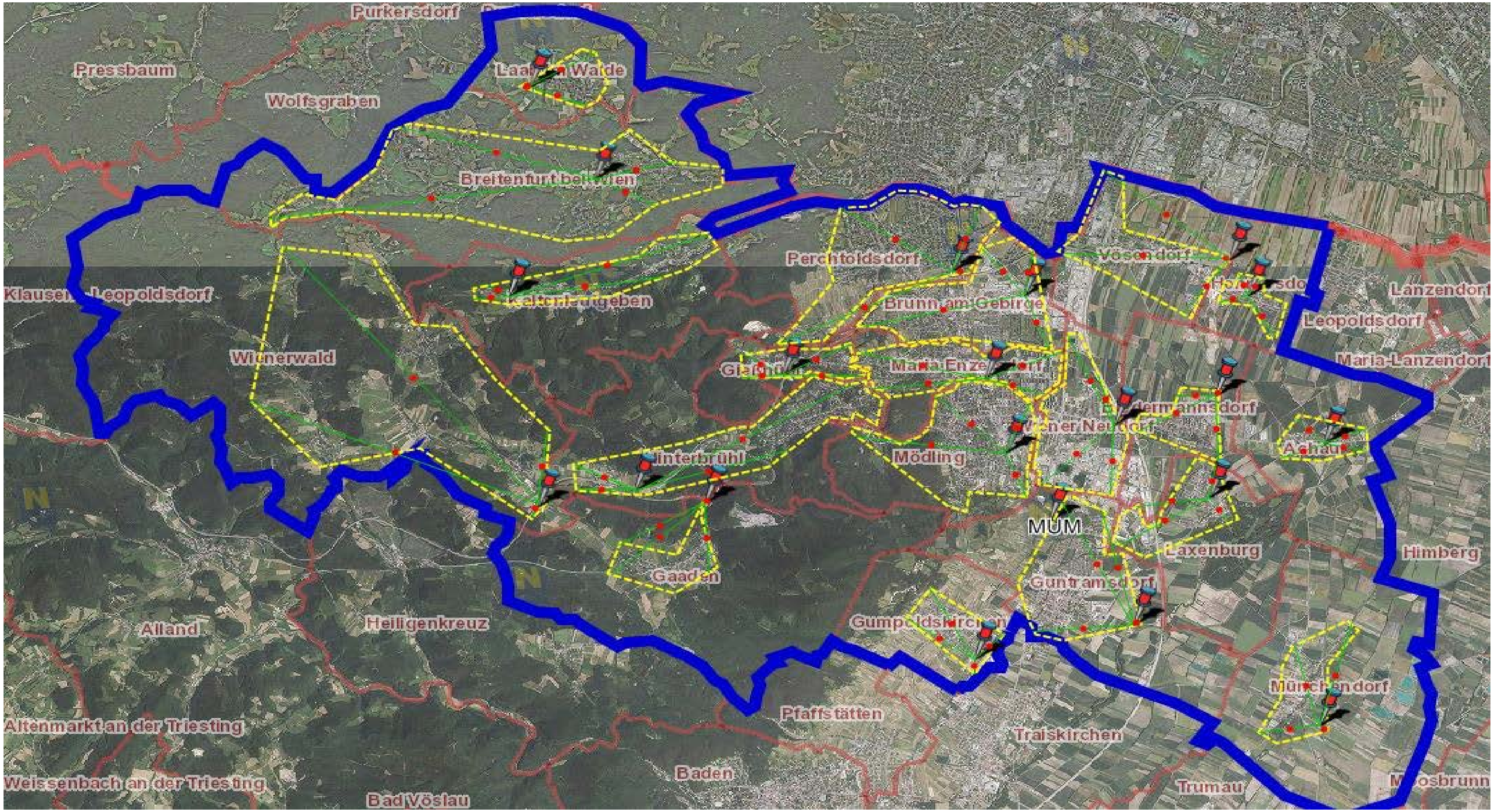

Figure 8. – Geographical distribution of simulated ASZ across the district Mödling (blue line) and within municipalities (red lines). Green lines indicate maximal distances within inhabited areas (yellow dotted lines); Red dots represent 50% of the maximal linear distances; scale 1:105.000 (Amt der NÖ Landesregierung, 2014).

3.1.2. Waste Categorization

The different types of waste that can be collected at any ASZ in the district are shown in figure 9. There are 52 waste fractions that are categorized into 6 major groups. For reasons of clarity in figure 9 only fractions that were disposed in 2013 at the ASZ are shown. Night storage heaters, drilling emulsions, used oil spill treating materials, used oil barrels, not hardened resin residues, plastics/ ballads with residual contents and commercial waste (cassettes) were not collected in any ASZ in 2013 and belong all to the hazardous waste group.

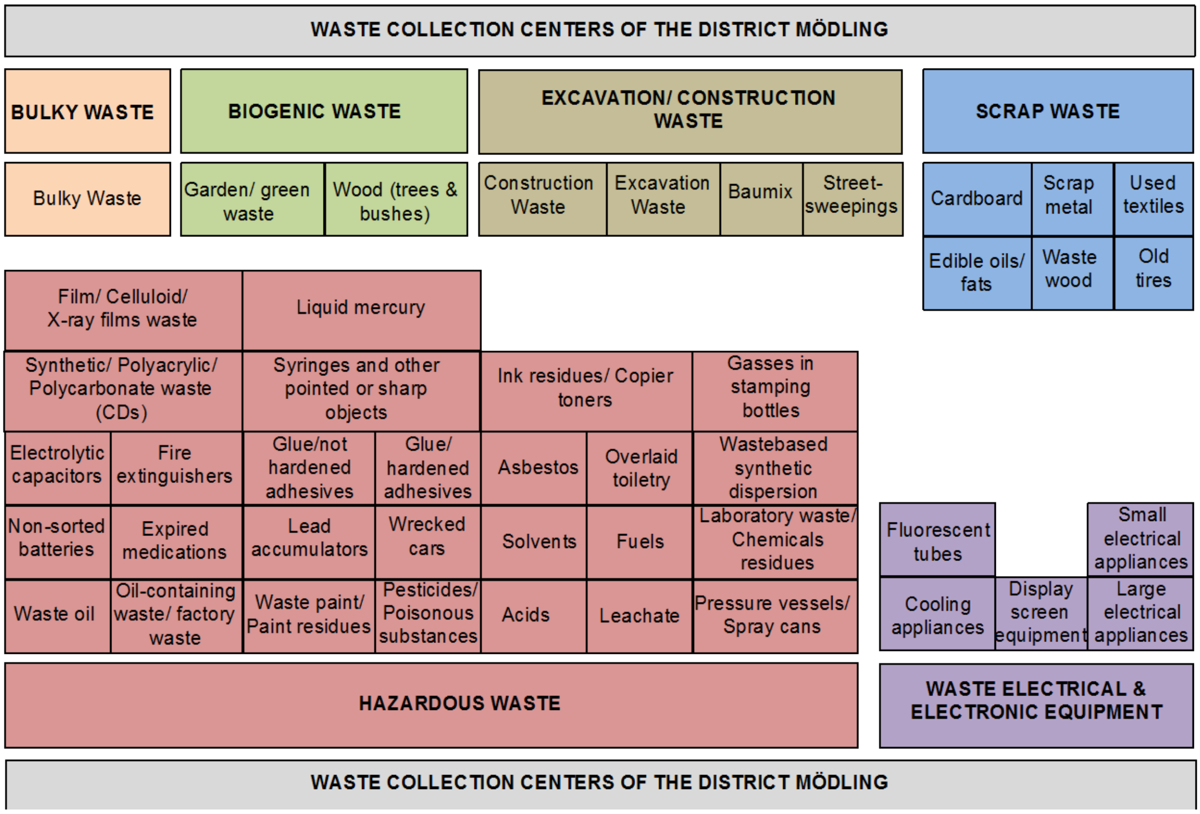

Figure 9. – Waste categorization according to EDM data (GVA Mödling , 2013).

3.1.3. Employed Methods for Collection and Storage of Waste Fractions

Employed methods for collection and storage options for different waste fractions are summarized in table 8. Figure 10 - figure 14 illustrate storage/ collection methods in different ASZ.

On-site inspections revealed that each ASZ provide a well-organized collection system. The employed storage options for different waste fractions ensure an efficient waste recycling system by using different sized and shaped but standardized methods (e.g. containers barrels, waste skips, grid boxes, etc.; table 8) in order to have an easy transport to and from the ASZ for authorized waste treatment operators. Waste is sorted and collected systematically at designated areas within every facility. Signs and the ASZ employees support locating the storage area for any particular waste fraction. Open containers are the most common method for storage and they are arranged to guarantee rapid and secure waste disposal for the ASZ users (figure 14). Waste skips and unspecific storage areas in particular for large volume waste (e.g. biogenic waste, figure 10) are arranged at areas that easily ensure disposal of large quantities of waste by providing e.g. appropriately dimensioned access roads and turning areas. Hazardous waste was mostly stored in standardized barrels at designated indoor areas (figure 13).

Table 8. – Employed methods for collection and storage of waste fractions according to EDM data (GVA Mödling , 2013).

Containers	Bulky waste, Waste wood, Garden/green waste, Old tires, Wood (trees and bushes), Cardboard, Used textiles, Scrap metal
Press Containers	Bulky waste, Cardboard
Grid boxes	Edible oils/fats, Fire extinguishers, Old tires, Display screen equipment, Small electrical appliances
Barrels	Waste oil, Waste paint/ Paint residues, Acids, Leachate, Pressure vessels/ Spray cans, Liquid mercury, Fuels, Solvents, Oil-containing waste/ Factory waste, Pesticides/ Poisonous substances, Expired medications, Non-sorted batteries, Laboratory waste/ Chemical residues, Overlaid toiletry, Used oil barrels, Ink residues/ Copier toners, Not hardened resin residues, Glue/ not hardened adhesives, Glue/ hardened adhesives, Film/ Celluloid/ X-ray films waste, Plastics/ ballads with residual contents, Synthetic/ Polyacrylic/ Polycarbonate waste (CDs), Wastebased synthetic dispersion, Electrolytic capacitors, Drilling emulsions/ Grinding emulsions, Used oil spill treating materials, Fluorescent tubes,
Waste skips	Construction waste, Asbestos

No specific storage areas	Cooling appliances, Large electrical appliances, Garden/green waste, Wood (trees and bushes), Cardboard, Scrap metal, Night storage heater, Wrecked cars
Post pallets	Fluorescent tubes
Home pickup service	Used textiles

Figure 10. – Unspecific storage area for garden/green waste.

Figure 11. –Unspecific storage area for old tires.

Figure 12. – Grid boxes.

Figure 13. – Barrels for different hazardous waste.

Figure 14. – Large containers for different waste fractions.

3.1.4. Demographic Data and Total Waste Collected

Population data for the district of Mödling and its 20 municipalities, as well as the absolute number of total waste generated in 2013 and adjusted to inhabitants are shown in table 9.

The absolute numbers of municipal waste emerged in Mödling (district) varied substantially among communes and was approximately 23-fold higher in Brunn a. Gebirge with the largest amount collected as compared with Laab im Walde that produced the least of all across the district. On the contrary, data standardized to inhabitants show a more homogenous pattern and differed maximally roughly four-fold between municipalities (Gaaden vs. Münchendorf) indicating that the absolute amount of collected waste is largely dependent on the municipalities population. Gaaden, Brunn a. Gebirge and Breitenfurt b. Wien produced the largest amounts per inhabitant (568 kg - 621 kg) that was approximately two-fold higher than the average within the entire district (307 kg/ inhabitant) whereas at the lower end, numbers ranged from 150 - 170 kg/ inhabitant (Münchendorf, Hinterbrühl and Guntramsdorf, respectively).

Table 9. – Demographic data, total generated waste in 2013 (tons) and standardized data (kg/inhabitant) [1] (Amt der NÖ Landesregierung, n.d.c), [2] (GVA Mödling , 2013).

Municipality	**Inhabitants 2013[1]**	**Total waste tons[2] | [kg/inhabitant]**
Achau	1.246	310 [249]
Biedermannsdorf	2.834	819 [289]
Breitenfurt b. Wien	5.810	3.402 [586]
Brunn a. Gebirge	11.366	6.914 [608]
Gaaden	1.599	994 [621]
Gießhübl	2.195	597 [272]
Gumpoldskirchen	3.663	1.394 [380]
Guntramsdorf	9.028	1.537 [170]
Hennersdorf	1.411	432 [306]
Hinterbrühl	4.066	693 [170]
Kaltenleutgeben	3.330	862 [259]
Laab im Walde	1.153	297 [257]
Laxenburg	2.820	1.196 [424]
Maria Enzersdorf	8.647	2.498 [289]
Mödling	20.457	3.680 [180]
Münchendorf	2.728	409 [150]
Perchtoldsdorf	14.636	4.351 [297]
Vösendorf	6.512	2.190 [336]
Wiener Neudorf	8.836	2.069 [234]
Wienerwald	2.488	663 [267]
District Mödling	**114.825**	**35.307 [307]**

3.1.5. Waste Groups and Fractions of Collected Waste

The absolute numbers of collected waste fractions are summarized in the appendix (table 21 - 26). Similar to the total amount of collected waste (chapter 3.1.4.), standardized data of different waste categories and their subgroups varied less than unadjusted numbers (= total numbers), indicating that different amounts of collected waste were partly dependent on the population size. In figure 15 the proportions of the 6 major waste groups for each ASZ and for the entire district are presented.

The highest amount of collected waste in the district Mödling was of biogenic origin (total: 43.9%; 31.3% garden/green waste and 12.6% wood respectively) followed by excavation/ construction waste (27.0%) and similar amounts of scrap (13.2%) and bulky waste (12.9%). Waste electrical & electronic equipment (WEEE) (1.8%) and hazardous waste (1.2%) represent the smallest groups. The major fraction of the excavation/ construction waste group emerged from construction waste (20.7 % in relation to total collected waste) and minor amounts of street-sweepings (4.0%), excavation waste (2.0%) and “Baumix” (0.4%), respectively. The acquired percentage of scrap waste was primarily driven by waste wood collection (8.1%) and approximately 4- up to 81-fold smaller amounts of the other fractions in this group (2.2% scrap metal, 1.8% cardboard, 0.8% used textiles, 0.2% edible oils/ fats and 0.1% old tires, respectively). Total district WEEE was composed of similar rates of cooling appliances, display screen equipment, large and small electrical appliances ranging from 0.3% - 0.6% whereas the fraction of fluorescent tubes was minimal (<0.1%). Similar small proportions were observed in fractions of hazardous waste ranging from <0.1% - 0.4%. Waste paint/ paint residues (0.4%) and asbestos (0.3%) were the leading fractions in this group.

Individual proportions of waste categories and its fractions varied substantially among ASZ. However, waste of each group was disposed at all ASZ except for Münchendorf where no biogenic waste was dropped-off and thus the relative amount of WEEE and hazardous waste was higher compared to other ASZ. Similar to the waste proportions of the entire district, biogenic waste was the most prominent in roughly two-thirds of the ASZ (range: 16.5% [Wienerwald] - 72.3% [Laxenburg]; figure 15) although the amount of collected fractions (garden/ green waste vs. wood) in this group appeared to be inconsistent throughout ASZ (table 22, appendix). Regarding the rank order of proportions of excavation/ construction waste, bulky waste and scrap waste no homogenous pattern could be observed in these groups as compared with the entire district. However, categories of WEEE and hazardous waste represented the smallest groups across ASZ in 2013 (0.9% - 2.7% for WEEE and 0.5% - 5.8% for hazardous waste), which is consistent with the total district data.

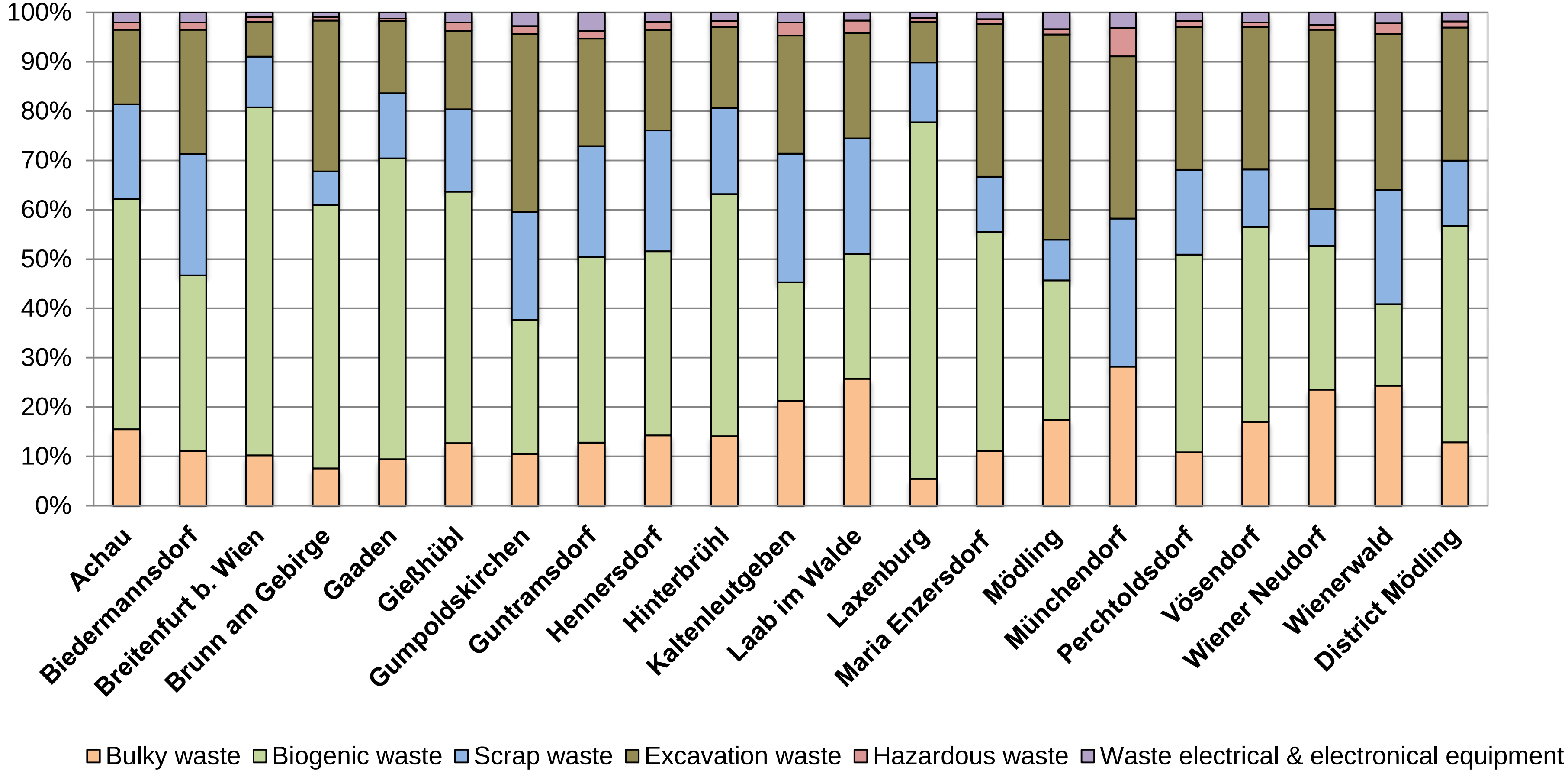

Figure 15. – Proportions of the 6 major waste groups for each ASZ and for the entire district according to EDM data (GVA Mödling , 2013).

3.1.6. MFA Diagrams of the District of Mödling

Figure 16 illustrates the material flow of the different waste groups collected in the district of Mödling in the year 2013. Proportions of the 6 major waste groups have already been presented in chapter 3.1.5. 37.8% of the total collected waste in the district was composted, followed by 24.1% that was landfilled and 23.8% utilized in incinerators. 10.0% of disposed waste was recycled, whereas only small proportions were shredded (2.4%), treated in EAG processing plants (1.8%) and refineries (0.1%), respectively.

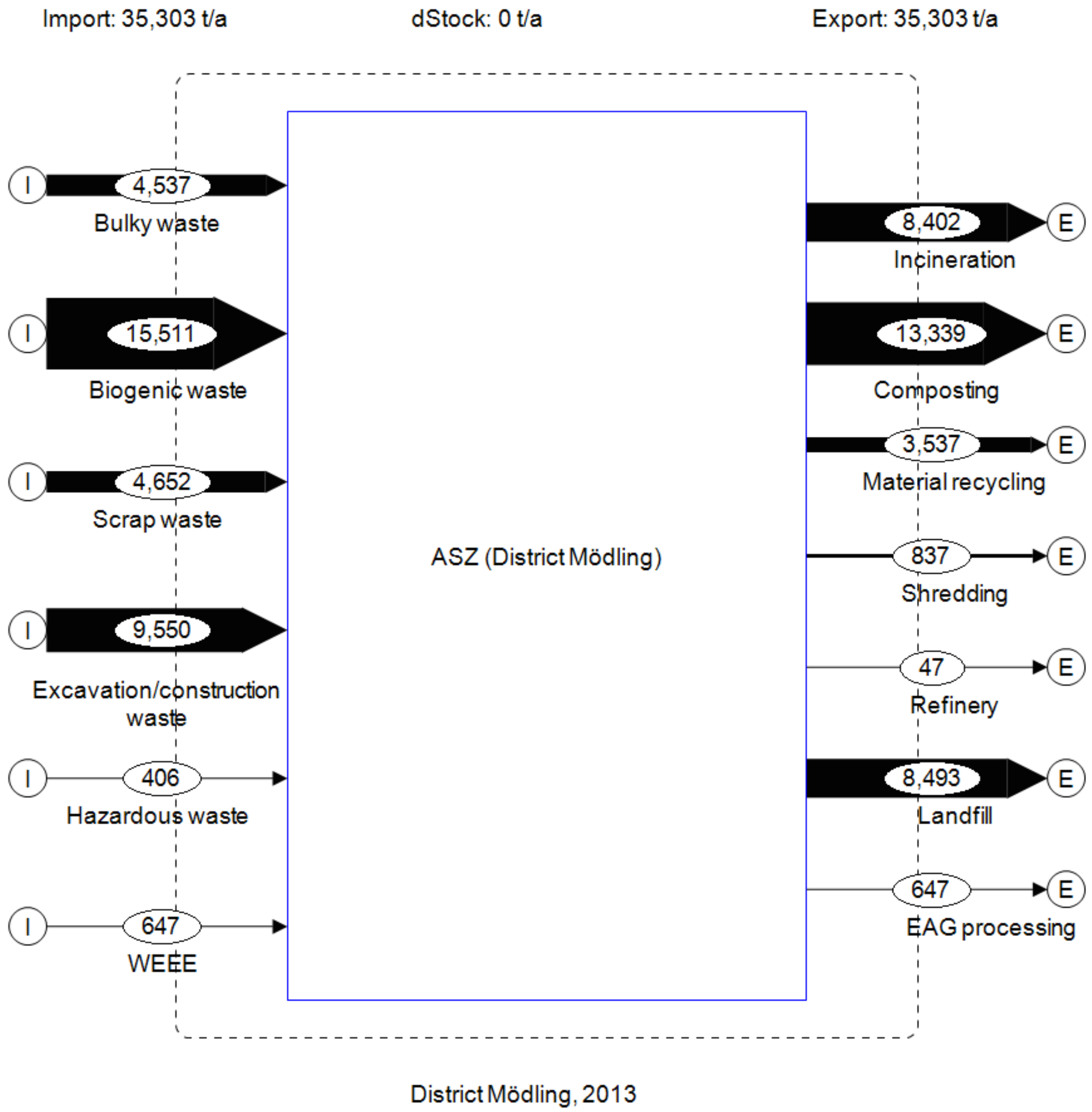

Figure 16. – Material flow of the different waste categories in the district of Mödling according to EDM data (GVA Mödling , 2013).

Figure 17 shows a more detailed MFA of the utilization of collected waste within the district using different treatment methods. Wastes of different groups enter into the system, where they are getting sorted and distributed to multiple types of collection methods. Consequently, the waste will be reallocated to the respective utilization methods.

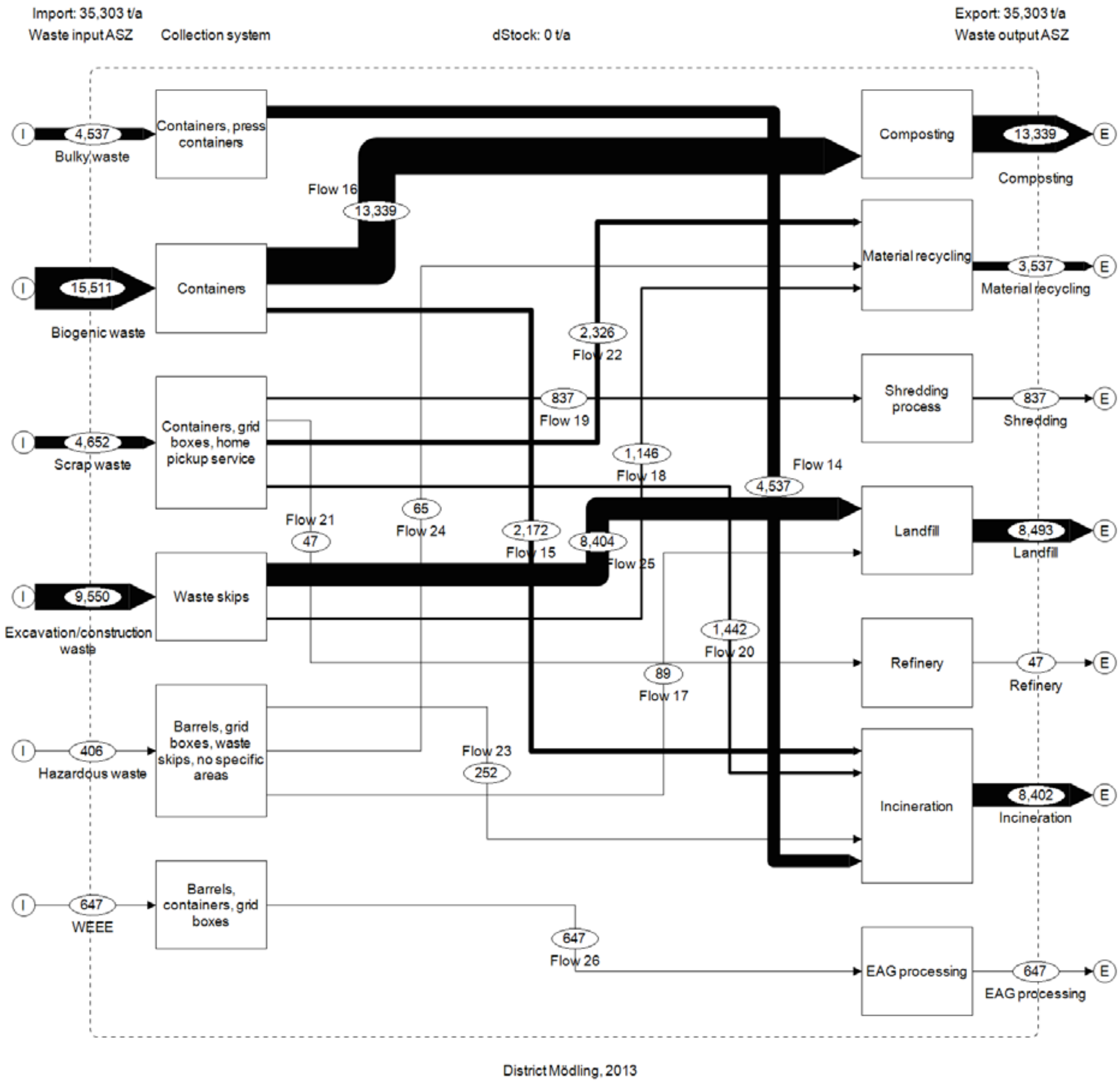

Figure 17. – Material flow of the waste collection in the district according to EDM data (GVA Mödling , 2013).

100% of bulky waste and WEEE were utilized in incinerators and EAG processing plants, respectively. 14.0% of biogenic waste was also incinerated whereas 86.0% were composted. Scrap waste represented the group with the most of all utilization methods. 50.0% were recycled, 31.0% incinerated, 18.0% shredded and 1.0% were treated in refineries. Most of excavation/ construction waste was landfilled (88.0%), while only a smaller amount was recycled (12.0%). For hazardous waste three different utilization methods were employed: incineration (62.1%), material recycling (16.0%) and landfilling (21.9%).

3.1.7. Disposal Fees and Extra Drop-off Fees

Extra charged disposal fees for old tires, wood, construction waste, bulky waste, garden/ green waste and asbestos are presented in table 10 and table 11, respectively. This data indicates that in many municipalities no extra fees were generated for waste fractions that are free of charge in household quantities.

Table 10. – Extra drop-off fees for old tires. Calculations were based on provided EDM data (GVA Mödling , 2013).

Municipality	**Drop-off fees (€)**			
	W/o rim	**W/rim**	**Tractor tire**	**Total**
Achau	89	23	45	**157**
Biedermannsdorf	80	20	45	**145**
Breitenfurt b. Wien	183	43	105	**331**
Brunn a. Gebirge	547	125	285	**957**
Gaaden	85	20	45	**150**
Gießhübl	41	10	30	**81**
Gumpoldskirchen	223	53	120	**396**
Guntramsdorf	124	30	75	**229**
Hennersdorf	58	15	30	**103**
Hinterbrühl	126	30	75	**231**
Kaltenleutgeben	249	58	135	**442**
Laab im Walde	17	5	15	**37**
Laxenburg	32	8	30	**70**
Maria Enzersdorf	149	35	90	**274**
Mödling	952	218	495	**1.665**
Münchendorf	254	60	135	**449**
Perchtoldsdorf	412	95	210	**717**
Vösendorf	416	95	210	**721**
Wiener Neudorf	0	0	0	**0**
Wienerwald	287	68	150	**505**
District Mödling	**4.324**	**1.008**	**2.325**	**7.657**

Table 11. – Extra drop-off fees for different waste fractions. Calculations were based on provided EDM data (GVA Mödling , 2013) [1] (Amt der NÖ Landesregierung, n.d.c).

Municipality	Households[1]	Wood (bushes, trees)		Construction waste		Bulky waste		Garden/green waste		Asbestos	
		Units	Drop-off Fees (€)	Units	Drop-off Fees (€)	Units	Drop-off Fees (€)	Units	Drop-off Fees (€)	Units	Drop-off Fees (€)
Achau	533	114	0	73	0	121	0	189	0	0	0
Biedermannsdorf	1.224	670	0	302	0	228	0	174	0	0	0
Breitenfurt b.Wien	2.476	7.072	55.152	371	0	871	0	700	0	29	725
Brunn a. Gebirge	5.114	2.404	0	2.499	0	1.312	0	5.028	0	49	1.225
Gaaden	645	450	0	224	0	235	0	800	2.480	0	0
Gießhübl	849	0	0	104	0	190	0	508	0	12	300
Gumpoldskirchen	1.677	1.355	0	774	0	365	0	0	0	33	825
Guntramsdorf	4.042	0	0	517	0	492	0	964	0	17	425
Hennersdorf	642	0	0	136	0	155	0	269	0	0	0
Hinterbrühl	1.598	0	0	175	0	245	0	567	0	8	200
Kaltenleutgeben	1.512	246	0	318	0	460	0	231	0	16	400
Laab im Walde	454	0	0	98	0	192	0	125	0	11	275
Laxenburg	1.156	1.097	0	152	0	163	0	930	0	8	200
Maria Enzersdorf	3.908	1.077	0	746	0	693	0	1.347	0	21	525
Mödling	9.655	0	0	783	0	1.605	0	1.732	0	0	0
Münchendorf	1.141	0	0	207	0	289	0	0	0	26	650
Perchtoldsdorf	6.533	0	0	1.377	0	1.182	0	2.906	0	14	350
Vösendorf	2.821	0	0	975	0	932	0	1.443	0	0	0
Wiener Neudorf	4.081	1.078	0	1.156	0	1.218	0	503	0	0	0
Wienerwald	1.005	391	0	239	0	404	0	0	0	14	350
District Mödling	**51.066**	**15.954**	**55.152**	**11.226**	**0**	**11.352**	**0**	**18.416**	**2.480**	**258**	**6.450**

3.2. Approach for Improvement of the Present Waste Management System

3.2.1. Geographical Optimization – Introduction of Scenarios

Scenario 1

Figure 18 (page 45) illustrates the simulation of a dramatic reduction in the number of ASZ across the district by 86% to three ASZ for all citizens. Table 12 summarizes the individual mean linear distances between the inhabited areas in the NE, SE, SW and NW of each municipality and their nearest ASZ (North, East or South).

As expected, the ASZ East (MUM) is the closest waste disposal center for 13 municipalities of the district, followed by the ASZ South (Hinterbrühl, n=4) and ASZ North (Breitenfurth b. Wien, n=3), respectively. As a consequence of the ASZ reduction, most citizens experience greater distances to their nearest ASZ as compared to the present situation (chapter 3.1.1) ranging from 0.6 km (Hinterbrühl) to 7.5 km (Münchendorf) which indicates a maximum increase of up to +7.4 km (Münchendorf). However, for three municipalities (Gaaden, Guntramsdorf, Kaltenleutgeben) a slight decrease in distances could be observed in at least one area of the respective municipalities (range: -0.1 km to -0.3 km). Distances across municipalities for this simulation did not exceed the maximum distance as assessed for the present situation (chapter 3.1.1., table 7, page 28)

Table 12. – Mean linear distances (lower row of each panel) between the nearest ASZ (upper row of each panel) and inhabited areas of municipalities across the district situation ASZ (GVA Mödling, n.d.b) (Amt der NÖ Landesregierung 2014) (Google, n.d.). Distances in brackets indicate additional kilometers as compared with the present situation.

Municipality	**Location within the inhabited area**			
	North-East	**South-East**	**South-West**	**North-West**
Achau	ASZ East 6.4 (+6.0)	ASZ East 6.3 (+5.9)	ASZ East 5.5 (+5.1)	ASZ East 5.7 (+5.3)
Biedermannsdorf	ASZ East 4.4 (+4.4)	ASZ East 4.0 (+3.3)	ASZ East 3.5 (+2.6)	ASZ East 4.1 (+3.7)
Breitenfurt b. Wien	ASZ North 0.9 (+-0)	ASZ North 0.7 (+-0)	ASZ North 3.4 (+-0)	ASZ North 2.1 (+-0)
Brunn a. Gebirge	ASZ East 5.7 (+5.2)	ASZ East 4.5 (+3.9)	ASZ East 5.3 (+3.6)	ASZ East 5.8 (+5.1)
Gaaden	ASZ South 1.5 (+1.5)	ASZ South 1.9 (+1.1)	ASZ South 1.2 (-0.1)	ASZ South 1.0 (+-0)
Gießhübl	ASZ South 4.8 (+4.0)	ASZ South 4.7 (+3.9)	ASZ South 3.7 (+3.3)	ASZ South 4.0 (+3.0)

Municipality	Location within the inhabited area			
	North-East	South-East	South-West	North-West
Gumpoldskirchen	ASZ East 3.2 (+2.8)	ASZ East 3.7 (+3.6)	ASZ East 3.6 (+2.8)	ASZ East 3.2 (+2.3)
Guntramsdorf	ASZ East 1.8 (+0.5)	ASZ East 3.0 (+3.0)	ASZ East 2.6 (+1.6)	ASZ East 1.4 (-0.2)
Hennersdorf	ASZ East 6.8 (+6.6)	ASZ East 6.4 (+5.9)	ASZ East 6.3 (+6.0)	ASZ East 6.7 (+6.5)
Hinterbrühl	ASZ South 2.6 (+-0)	ASZ South 1.7 (+-0)	ASZ South 0.6 (+-0)	ASZ South 0.7 (+-0)
Kaltenleutgeben	ASZ North 1.9 (-0.3)	ASZ North 2.4 (+0.8)	ASZ North 3.4 (+3.1)	ASZ North 3.1 (+2.9)
Laab im Walde	ASZ North 2.7 (+1.9)	ASZ North 2.1 (+1.5)	ASZ North 2.6 (+2.6)	ASZ North 2.6 (+2.6)
Laxenburg	ASZ East 3.4 (+3.1)	ASZ East 3.5 (+3.2)	ASZ East 2.4 (+1.3)	ASZ East 2.6 (+1.9)
Maria Enzersdorf	ASZ East 3.6 (+2.8)	ASZ East 3.1 (+2.5)	ASZ East 4.0 (+2.9)	ASZ East 4.4 (+3.1)
Mödling	ASZ East 2.2 (+1.6)	ASZ East 1.3 (+0.8)	ASZ East 3.0 (+1.5)	ASZ East 2.7 (+1.7)
Münchendorf	ASZ East 6.9 (+5.7)	ASZ East 7.5 (+7.4)	ASZ East 6.9 (+6.3)	ASZ East 6.5 (+5.6)
Perchtoldsdorf	ASZ East 6.7 (+5.9)	ASZ East 6.0 (+5.9)	ASZ East 6.2 (+4.3)	ASZ East 7.2 (+5.9)
Vösendorf	ASZ East 7.0 (+7.0)	ASZ East 6.2 (+5.4)	ASZ East 6.4 (+4.7)	ASZ East 7.4 (+5.8)
Wiener Neudorf	ASZ East 3.0 (+2.4)	ASZ East 1.8 (+1.0)	ASZ East 1.6 (+0.6)	ASZ East 2.1 (+3.2)
Wienerwald	ASZ South 2.0 (+1.2)	ASZ South 2.1 (+1.9)	ASZ South 5.1 (+1.9)	ASZ South 5.0 (+1.0)

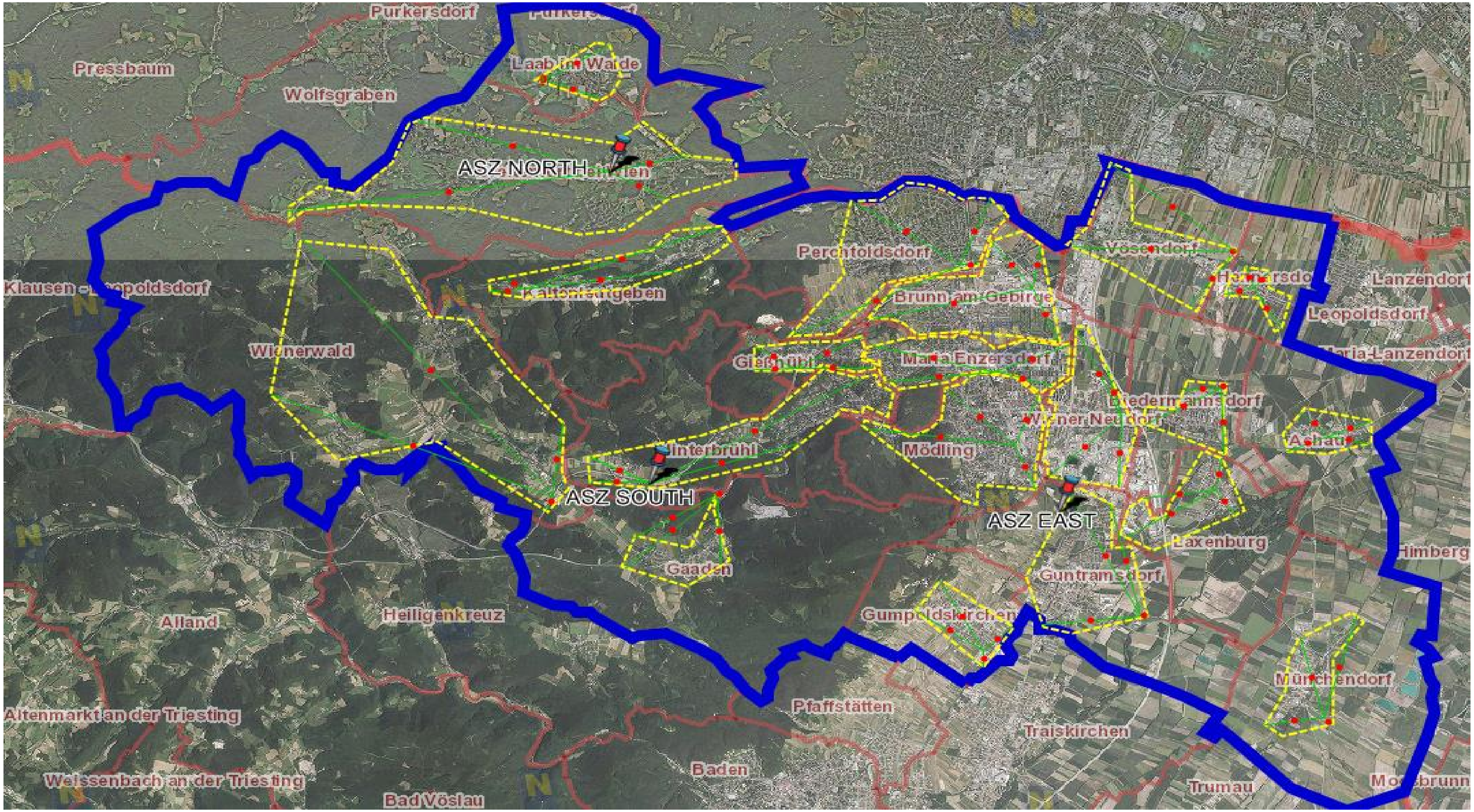

Figure 18. – Geographical distribution of simulated ASZ (North, East & South) across the district (blue line). Red dots (50% of maximal linear distance for status quo) indicate reference points for assessment of mean linear distances between inhabited areas (yellow dotted lines) of each municipality (red lines) and ASZ; scale 1:105.000 (Amt der NÖ Landesregierung, 2014).

Scenario 2

Another simulation with a reduction of ASZ by only one third (=14 remaining ASZ) for the entire district is shown Figure 19 (page 48). Table 13 summarizes the individual mean linear distances between the inhabited areas in the NE, SE, SW and NW of each municipality and their nearest ASZ.

Distances for nearly all municipalities with persistent ASZ remained unchanged as compared with the present situation but in some areas of them even a decrease (Breitenfurt b. Wien, Hinterbrühl, Kaltenleutgeben) of up to -0.9 km could be observed which is likely due to permission to any ASZ within the district for its inhabitants in simulated scenarios.

For municipalities with no ASZ in this simulation, distances ranged from 0.9 km (Vösendorf) to 4.3 km (Wienerwald) and increased only slightly by +3.0 km for inhabitants of the SE area of Guntramsdorf that represents the highest additional distance although in another area of this municipality a decrease could be assessed (-0.2 km, NW area). The highest decrease in distance covered was observed for Wienerwald with -1.2 km for households in the NW.

Table 13. – Mean linear distances (lower row of each panel) between the nearest ASZ (upper row of each panel) and inhabited areas of municipalities across the district (GVA Mödling, n.d.b) (Amt der NÖ Landesregierung, 2014) (Google, n.d.). Distances in brackets indicate additional kilometers as compared with the present situation.

Municipality	**Location within the inhabited area**			
	North-East	**South-East**	**South-West**	**North-West**
Achau	ASZ Achau 0.5 (+-0)	ASZ Achau 0.4 (+-0)	ASZ Achau 0.5 (+-0)	ASZ Achau 0.4 (+-0)
Biedermannsdorf	ASZ Biedermannsdorf 0.1 (+-0)	ASZ Biedermannsdorf 0.8 (+-0)	ASZ Biedermannsdorf 0.9 (+-0)	ASZ Biedermannsdorf 0.4 (+-0)
Breitenfurt b. Wien	ASZ Breitenfurt b. Wien 0.9 (+-0)	ASZ Breitenfurt b. Wien 0.7 (+-0)	ASZ Kaltenleutgeben 2.7 (-0.7)	ASZ Laab im Walde 1.6 (-0.5)
Brunn a. Gebirge	ASZ Brunn a. Gebirge 0.5 (+-0)	ASZ Brunn a. Gebirge 0.7 (+-0)	ASZ Brunn a. Gebirge 1.7 (+-0)	ASZ Brunn a. Gebirge 0.7 (+-0)
Gaaden	ASZ Hinterbrühl 1.5 (+1.5)	ASZ Hinterbrühl 1.8 (+1.0)	ASZ Hinterbrühl 1.2 (-0.1)	ASZ Hinterbrühl 0.9 (-0.1)
Gießhübl	ASZ Gießhübl 0.8 (+-0)	ASZ Gießhübl 0.8 (+-0)	ASZ Gießhübl 0.4 (+-0)	ASZ Gießhübl 0.5 (+-0)
Gumpoldskirchen	ASZ Gumpoldskirchen 0.4 (+-0)	ASZ Gumpoldskirchen 0.2 (+-0)	ASZ Gumpoldskirchen 0.9 (+-0)	ASZ Gumpoldskirchen 0.9 (+-0)
Guntramsdorf	ASZ MUM 1.8 (+0.5)	ASZ MUM 3.0 (+3.0)	ASZ Gumpoldskirchen 2.4 (+1.4)	ASZ MUM 1.4 (-0.2)
Hennersdorf	ASZ Hennersdorf 0.3 (+-0)	ASZ Hennersdorf 0.6 (+-0)	ASZ Hennersdorf 0.3 (+-0)	ASZ Hennersdorf 0.3 (+-0)

Municipality	Location within the inhabited area			
	North-East	**South-East**	**South-West**	**North-West**
Hinterbrühl	ASZ Gießhübl 1.7 (-0.9)	ASZ Hinterbrühl 1.7 (+-0)	ASZ Hinterbrühl 0.6 (+-0)	ASZ Hinterbrühl 0.7 (+-0)
Kaltenleutgeben	ASZ Breitenfurt b. Wien 2.0 (-0.2)	ASZ Kaltenleutgeben 1.6 (+-0)	ASZ Kaltenleutgeben 0.4 (+-0)	ASZ Kaltenleutgeben 0.3 (+-0)
Laab im Walde	ASZ Laab im Walde 0.8 (+-0)	ASZ Laab im Walde 0.7 (+-0)	ASZ Laab im Walde 0.1 (+-0)	ASZ Laab im Walde 0.1 (+-0)
Laxenburg	ASZ Laxenburg 0.4 (+-0)	ASZ Laxenburg 0.4 (+-0)	ASZ Laxenburg 1.1 (+-0)	ASZ Laxenburg 0.8 (+-0)
Maria Enzersdorf	ASZ Brunn a. Gebirge 1.6 (+0.8)	ASZ Mödling 1.6 (+1.0)	ASZ Mödling 2.2 (+1.1)	ASZ Mödling 2.6 (+1.3)
Mödling	ASZ Mödling 0.6 (+-0)	ASZ Mödling 0.6 (+-0)	ASZ Mödling 1.6 (+-0)	ASZ Mödling 1.0 (+-0)
Münchendorf	ASZ Münchendorf 1.2 (+-0)	ASZ Münchendorf 0.1 (+-0)	ASZ Münchendorf 0.6 (+-0)	ASZ Münchendorf 1.0 (+-0)
Perchtoldsdorf	ASZ Brunn a. Gebirge 1.8 (+1.0)	ASZ Brunn a. Gebirge 1.4 (+1.3)	ASZ Gießhübl 2.3 (+0.4)	ASZ Brunn a. Gebirge 3.0 (+1.7)
Vösendorf	ASZ Hennersdorf 1.0 (+1.0)	ASZ Hennersdorf 0.9 (+0.1)	ASZ Hennersdorf 2.4 (+0.7)	ASZ Hennersdorf 2.5 (+0.9)
Wiener Neudorf	ASZ Biedermannsdorf 2.3 (+1.7)	ASZ MUM 1.9 (+1.1)	ASZ Mödling 1.5 (+0.5)	ASZ Mödling 2.4 (+1.3)
Wienerwald	ASZ Hinterbrühl 2.0 (+1.2)	ASZ Hinterbrühl 2.1 (+1.9)	ASZ Kaltenleutgeben 4.3 (+1.1)	ASZ Kaltenleutgeben 2.7 (-1.2)

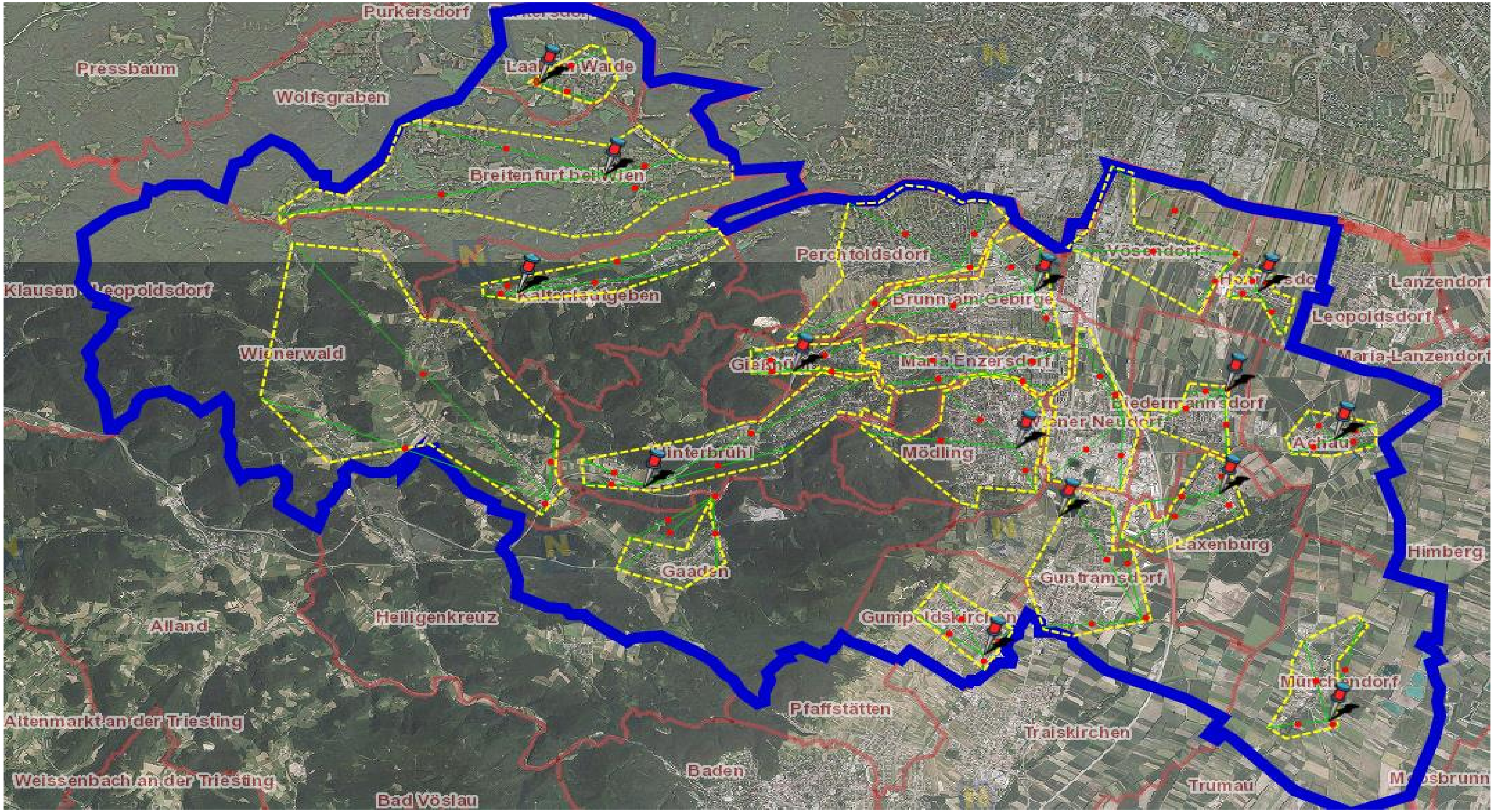

Figure 19. – Geographical distribution of simulated ASZ (n=14) across the district (blue line). Red dots (50% of maximal linear distance for status quo) indicate reference points for assessment of mean linear distances between inhabited areas (yellow dotted lines) of each municipality (red lines) and ASZ; scale 1:105.000 (Amt der NÖ Landesregierung, 2014).

3.2.2. Total Distances & Ecological Indicators

Table 14. – Distance (km), diesel consumption (l) and CO_2 emissions (kg) for the present situation and for simulated scenarios.[1, 2] indicates municipalities with remaining ASZ in scenario 1 ([1]) and scenario 2 ([2]), respectively.

Municipality	Distance/ year (km)			Diesel/ year (l)			CO_2 / year (kg)		
	Present Situation	Scenario 1	Scenario2	Present Situation	Scenario 1	Scenario2	Present Situation	Scenario 1	Scenario2
Achau[2]	4.236	59.559	4.236	288	4.050	288	763	10.721	763
Biedermannsdorf[2]	11.903	90.688	11.903	809	6.167	809	2.143	16.324	2.143
Breitenfurt b. Wien[1,2]	81.340	81.340	67.396	5.531	5.531	4.583	14.641	14.641	12.131
Brunn a. Gebirge[2]	80.699	484.192	80.699	5.488	32.925	5.488	14.526	87.154	14.526
Gaaden	9.914	17.909	17.269	674	1.218	1.174	1.784	3.224	3.108
Gießhübl[2]	10.975	75.069	10.975	746	5.105	746	1.976	13.512	1.976
Gumpoldskirchen[2]	16.850	100.366	16.850	1.146	6.825	1.146	3.033	18.066	3.033
Guntramsdorf	72.224	158.893	155.278	4.911	10.805	10.559	13.000	28.601	27.950
Hennersdorf[2]	3.810	73.936	3.810	259	5.028	259	686	13.309	686
Hinterbrühl[1,2]	44.726	44.726	37.814	3.041	3.041	2.571	8.051	8.051	6.806
Kaltenleutgeben[2]	29.304	71.928	27.972	1.993	4.891	1.902	5.275	12.947	5.035
Laab im Walde[2]	3.574	23.060	3.574	243	1.568	243	643	4.151	643
Laxenburg[2]	14.382	67.116	14.382	978	4.564	978	2.589	12.081	2.589
Maria Enzersdorf	67.447	261.139	138.335	4.586	17.757	9.407	12.140	47.005	24.900
Mödling[2]	151.382	376.409	151.382	10.294	25.596	10.294	27.249	67.754	27.249
Münchendorf[2]	15.550	151.677	15.550	1.057	10.314	1.057	2.799	27.302	2.799
Perchtoldsdorf	124.406	763.999	248.806	8.460	51.952	16.919	22.393	137.520	44.785
Vösendorf	54.701	351.648	88.563	3.720	23.912	6.022	9.846	63.297	15.941
Wiener Neudorf	63.619	169.651	143.143	4.326	11.536	9.734	11.451	30.537	25.766
Wienerwald	40.554	72.152	55.234	2.758	4.906	3.756	7.300	12.987	9.942
Total	**901.595**	**3.495.457**	**1.293.170**	**61.308**	**237.691**	**87.936**	**162.287**	**629.182**	**232.771**

Table 14 summarizes the impact of ASZ reduction on annual distance covered, diesel consumption and CO_2 emissions across the district. These three indicators changed equally and were subject to variations among municipalities and between scenarios, respectively. In scenario 1 for Breitenfurt b. Wien and Hinterbrühl distance travelled and ecological indicators were unaltered as compared with the status quo due to remaining ASZ in these municipalities. For all other municipalities an increase in these parameters was calculated resulting in 1.8-fold (Gaaden) up to 19.4-fold (Hennersdorf) higher values in comparison to the present situation in the district.

In scenario 2 changes in environmental indicators were less pronounced and for Breitenfurt b. Wien, Hinterbrühl and Kaltenleutgeben even a decrease by -17%, -16% and -5% respectively, could be detected. In all other municipalities indicators remained unchanged (municipalities with ASZ) or increased at most by 2.3-fold (Wiener Neudorf).

For the entire district of Mödling there was a 3.9-fold (scenario 1) and 1.4-fold (scenario 2) increase in distance travelled, fuel consumption and CO_2 emissions detected.

3.2.3. Costs

3.2.3.1 Distribution of Citizens across ASZ

Assessment of investment costs and opening hours (that further affected operational costs) were based on inhabitants accessing the respective ASZ. Thus, in table 15 the distribution of citizens among ASZ for the present situation and the simulations are presented. Numbers for scenarios are derived by assuming that each citizen uses his/ her nearest ASZ according to table 12 and 13, respectively**.**

For the present situation numbers of ASZ user were the same as inhabitants of the respective municipality. In scenario 1 there was an inhomogeneous shift of more than 80% of the district´s population to the ASZ East (MUM) observed. The remaining citizens were almost equally distributed to the ASZ North and ASZ South, respectively. In the second simulation, this pattern was more regular and numbers of ASZ users did not exceed the upper range (20.457, Mödling) of the present situation except for Brunn a. Gebirge and Mödling with more than 24.000 and 31.000 users, respectively.

Table 15. – Distribution of citizens among ASZ for the present situation and for simulated scenarios.[1, 2] indicates municipalities with remaining ASZ in scenario 1 ([1]) and scenario 2 ([2]), respectively [3] (Amt der NÖ Landesregierung, n.d.c).

Municipality/ASZ	**Users of ASZ**		
	Present Situation[3]	**Scenario 1**	**Scenario 2**
Achau[2]	1.246	-	1.246
Biedermannsdorf[2]	2.834	-	5.043
Breitenfurt b. Wien[1,2]	5.810	10.293	3.738
Brunn a. Gebirge[2]	11.366	-	24.503
Gaaden	1.599	-	-
Gießhübl[2]	2.195	-	6.871
Gumpoldskirchen[2]	3.663	-	5.920
Guntramsdorf	9.028	-	-
Hennersdorf[2]	1.411	-	7.923
Hinterbrühl[1,2]	4.066	10.348	5.893
Kaltenleutgeben[2]	3.330	-	5.194
Laab im Walde[2]	1.153	-	2.606
Laxenburg[2]	2.820	-	2.820
Maria Enzersdorf	8.647	-	-
Mödling[2]	20.457	-	31.360
Münchendorf[2]	2.728	-	2.728
Perchtoldsdorf	14.636	-	-
Vösendorf	6.512	-	-
Wiener Neudorf	8.836	-	-
Wienerwald	2.488	-	-
MUM[1,2]	unknown	94.184	8.980
Total	**114.825**	**114.825**	**114.825**

3.2.3.2. Investment Costs

Table 16 summarizes the ASZ investment costs arising for the present situation and different simulations. In comparison to the status quo total estimated costs decreased by 72 % (- € 3.751.229) in scenario 1 and by 18% (- € 965.677) in scenario 2 for the entire district, respectively. In scenario 1 investment costs between ASZ North (Breitenfurt b. Wien) and ASZ South (Hinterbrühl) were similar, whereas they were approximately 43% higher for the ASZ East (MUM). Due to a higher number of remaining ASZ in the second simulation investment costs were more homogenous allocated among municipalities but differed by a factor of 5.1 at most between highest (Mödling) and lowest (Achau) expenditures.

Table 16. – Estimation of investment costs for the present situation and for simulated scenarios.[1, 2] indicates municipalities with remaining ASZ in scenario 1 ([1]) and scenario 2 ([2]), respectively.

Municipality/ASZ	**Investment costs (€)**		
	Present Situation	**Scenario 1**	**Scenario 2**
Achau[2]	102.666	-	102.666
Biedermannsdorf[2]	211.045	-	287.054
Breitenfurt b. Wien[1,2]	305.727	381.151	247.560
Brunn a. Gebirge[2]	394.229	-	495.542
Gaaden	135.564	-	-
Gießhübl[2]	177.347	-	327.848
Gumpoldskirchen[2]	244.887	-	308.200
Guntramsdorf	363.856	-	-
Hennersdorf[2]	119.068	-	346.637
Hinterbrühl[1,2]	258.653	381.854	307.597
Kaltenleutgeben[2]	232.317	-	290.945
Laab im Walde[2]	92.436	-	199.984
Laxenburg[2]	210.392	-	210.392
Maria Enzersdorf	358.169	-	-
Mödling[2]	471.740	-	528.084
Münchendorf[2]	206.018	-	206.018
Perchtoldsdorf	427.578	-	-
Vösendorf	320.771	-	-
Wiener Neudorf	361.021	-	-
Wienerwald	193.872	-	-
MUM[1,2]	unknown	673.123	363.153
Total	**5.187.357**	**1.436.128**	**4.221.680**

3.2.3.3. Operational Costs (Personnel and Maintenance Costs)

Table 17. – Estimation of the annual opening hours, personnel costs, and maintenance costs for the present situation and for simulated scenarios. [1, 2] indicates municipalities with remaining ASZ in scenario 1 ([1]) and scenario 2 ([2]), respectively. [3] (GVA Mödling, n.d.b)

Municipality	Opening Hours/ year (h)			Personnel Costs/ year (€)			Maintenance Costs/ year (€)		
	Present Situation[3]	Scenario 1	Scenario2	Present Situation	Scenario 1	Scenario2	Present Situation	Scenario 1	Scenario2
Achau[2]	104	-	48	5.834	-	2.693	2.132	-	984
Biedermannsdorf[2]	512	-	208	28.723	-	11.669	10.496	-	4.264
Breitenfurt b. Wien[1,2]	728	416	96	40.841	23.338	5.386	14.924	8.528	1.968
Brunn a. Gebirge[2]	1.560	-	416	87.516	-	23.338	31.980	-	8.528
Gaaden	208	-	-	11.669	-	-	4.264	-	-
Gießhübl[2]	286	-	208	16.045	-	11.669	5.863	-	4.264
Gumpoldskirchen[2]	416	-	208	23.338	-	11.669	8.528	-	4.264
Guntramsdorf	1.257	-	-	70.499	-	-	25.762	-	-
Hennersdorf[2]	208	-	208	11.669	-	11.669	4.264	-	4.264
Hinterbrühl[1,2]	728	416	208	40.841	23.338	11.669	14.924	8.528	4.264
Kaltenleutgeben[2]	1.284	-	208	72.032	-	11.669	26.322	-	4.264
Laab im Walde[2]	312	-	72	17.503	-	4.039	6.396	-	1.476
Laxenburg[2]	312	-	72	17.503	-	4.039	6.396	-	1.476
Maria Enzersdorf	1.001	-	-	56.156	-	-	20.521	-	-
Mödling[2]	1.976	-	416	110.854	-	23.338	40.508	-	8.528
Münchendorf[2]	273	-	72	15.315	-	4.039	5.597	-	1.476
Perchtoldsdorf	2.392	-	-	134.191	-	-	49.036	-	-
Vösendorf	572	-	-	32.089	-	-	11.726	-	-
Wiener Neudorf	1.300	-	-	72.930	-	-	26.650	-	-
Wienerwald	198	-	-	11.108	-	-	4.059	-	-
MUM[1,2]	2.340	416	208	131.274	23.338	11.669	47.970	8.528	4.264
Total	**17.967**	**1.248**	**2.648**	**1.007.930**	**70.013**	**148.553**	**368.317**	**25.584**	**54.284**

The annual opening hours and emerging operational costs consisting of personnel and maintenance costs for the ASZ across the district are shown in table 17. Due to their dependency on opening hours these expenditures changed consistently within scenarios and decreased for the entire district by 93% (scenario 1) and by 85% (scenario 2) as compared to the status quo. This indicates savings in annual operational costs of approximately € 1.280.000 in scenario 1 and € 1.117.000 in scenario 2, respectively. Opening hours declined sharply for individual remaining ASZ in both scenarios except for Hennersdorf (scenario 2) with no change compared to the present situation.

3.2.3.4. Fuel (Diesel) Costs

Table 18 summarizes an estimation of fuel costs for each municipality and the respective scenarios based on the annual distances travelled (table 14, chapter 3.2.2.). Thus, these costs changed in a similar manner as distances and ecological indicators (table 14) with unaltered costs in scenario 1 for Breitenfurt b. Wien and Hinterbrühl (remaining ASZ) and increases ranging from 1.8 fold higher costs for Gaaden up to 19.4-fold increased costs for Hennersdorf.

In the second simulation these changes were less pronounced and yet decreased by -17% (Breitenfurt b. Wien), -16% (Hinterbrühl) and -5% (Kaltleutengeben). Furthermore, for citizens of municipalities with remaining ASZ fuel costs were unchanged and in all other municipalities an increase with a maximum by a factor of 2.3 (Wiener Neudorf) was assessed.

Calculations of alterations for the entire district resulted in 3.9-fold (scenario 1) and 1.4-fold (scenario 2) increased fuel costs, respectively.

Table 18. – Estimation of the annual diesel costs for each municipality and [per inhabitant] based on table 14 and (ÖAMTC, n.d.).

Municipality	**Diesel costs/year (€), [€/inhabitant/year]**		
	Present Situation	**Scenario 1**	**Scenario2**
Achau	403 [0.3]	5.670 [4.6]	403 [0.3]
Biedermannsdorf	1.133 [0.4]	8.634 [3.1]	1.133 [0.4]
Breitenfurt b. Wien	7.744 [1.3]	7.744 [1.3]	6.416 [1.1]
Brunn a. Gebirge	7.683 [0.7]	46.095 [4.1]	7.683 [0.7]
Gaaden	944 [0.6]	1.705 [1.1]	1.645 [1.0]
Gießhübl	1.045 [0.5]	7.147 [3.3]	1.045 [0.5]
Gumpoldskirchen	1.604 [0.4]	9.555 [2.7]	1.604 [0.4]
Guntramsdorf	6.876 [0.8]	15.127 [1.7]	14.783 [1.6]
Hennersdorf	363 [0.3]	7.039 [5.0]	363 [0.3]
Hinterbrühl	4.258 [1.1]	4.258 [1.1]	3.600 [0.9]
Kaltenleutgeben	2.790 [0.8]	6.848 [2.1]	2.663 [0.8]
Laab im Walde	340 [0.3]	2.195 [1.9]	340 [0.3]
Laxenburg	1.369 [0.5]	6.390 [2.3]	1.369 [0.5]
Maria Enzersdorf	6.421 [0.7]	24.861 [2.9]	13.169 [1.5]
Mödling	14.412 [0.7]	35.834 [1.8]	14.412 [0.7]
Münchendorf	1.480 [0.5]	14.440 [5.3]	1.480 [0.5]
Perchtoldsdorf	11.844 [0.8]	72.733 [5.0]	23.686 [1.6]
Vösendorf	5.208 [0.8]	33.477 [5.1]	8.431 [1.3]
Wiener Neudorf	6.057 [0.7]	16.151 [1.8]	13.627 [1.5]
Wienerwald	3.861 [1.6]	6.869 [2.8]	5.258 [2.1]
Total	**85.832** [0.8]	**332.768** [2.9]	**123.110** [1.1]

3.2.3.5 Summary of Accruing Costs

Table 19 summarizes the expenditures for the entire district that were assessed during the optimization approach for municipalities (investment and operational costs) and for citizens (fuel costs) per year and inhabitant. Investment costs with an assumed depreciation period of 20 years decreased by 72% (scenario 1) and 19% (scenario 2) compared with the present situation. Operational costs represented the major expenditures for the status quo and were 93% and 85% lower in the first and second simulation, respectively. Different from these expenditures fuel cost increased 3.9-fold (scenario 1) and 1.4-fold (scenario 2) in comparison to the present situation. These changes resulted in an almost similar total cost reduction of 71% in scenario 1 and 69% in scenario 2, respectively, and were mainly driven by high operational costs in the present situation.

Table 19. – Total annually estimated investment, operational and fuel costs per inhabitant for the present situation and the simulations according to data from table 15-18.

	Present Situation	**Scenario 1**	**Scenario 2**
Investment costs (€/year/inhabitant)	2.3	0.6	1.8
Operational costs (€/year/inhabitant)	12.0	0.8	1.8
Fuel costs (€/year/inhabitant)	0.8	2.9	1.1
Total (€/year/inhabitant)	**15.1**	**4.3**	**4.7**

3.2.4. Summary of the Improvement Approach

Table 20 gives an overview of the assessed indicators for the district Mödling used to evaluate the present waste management system in comparison with different simulated scenarios following a reduction of ASZ. To sum up, changes for all indicators were more pronounced in scenario 1 than scenario 2 but within scenarios and between municipalities these alterations were subject to high variability. However, if there was for e.g. an increase for the entire district observed most of municipalities responded similar and only for a minority an inverse reaction (decrease) was observed.

Except for the mean distances to ASZ that changed highly inconsistently, distances travelled, ecological indicators (diesel, CO_2) and fuel costs increased equally within scenarios. A similar pattern was observed for investment costs, operational (personnel & maintenance) costs and ASZ opening hours that all followed a decrease.

Table 20. – Summary of indicators used for assessment of the present situation and different simulations. For scenarios decreases (🡻) and increases (🡹) compared with the present situation are shown. Numbers in brackets indicate ranges of additional kilometers, percent changes or x-fold changes compared with status quo.

Indicator	**Present Situation**	**Scenario 1**	**Scenario 2**
Mean distance to ASZ (km/year/inhabitant)	0.1 to 3.9	🡻🡹 (-0.1 to +7.4)	🡻🡹 (-1.2 to +3.0)
Total distance (km/year)	901.595	🡹 (3.9 x)	🡹 (1.4 x)
Total fuel consumption (l/year)	61.308	🡹 (3.9 x)	🡹 (1.4 x)
Total CO_2 emissions (kg/year)	162.287	🡹 (3.9 x)	🡹 (1.4 x)
Total investment costs (€)	5.187.357	🡻 (-72%)	🡻 (-18%)
Total opening hours (h/year)	17.967	🡻 (-93%)	🡻 (-85%)
Total personnel costs (€/year)	1.007.930	🡻 (-93%)	🡻 (-85%)
Total maintenance costs (€/year)	368.317	🡻 (-93%)	🡻 (-85%)
Total fuel costs (€/year), [€/year/inhabitant]	85.832 [0.8]	🡹 (3.9 x)	🡹 (1.4 x)

4. Discussion

4.1. Collected Waste and MFA

The first part of this study identified the different groups of waste and their fractions that can be disposed at any ASZ across the district. Independent from the size of population and thus the ASZ, all waste fractions could have been disposed at any ASZ. It is likely that the actual proportions between groups may differ since the amount of common types of waste such as lightweight packaging, used glass or metal (cans) could not be implemented in the analysis due to a paucity of data provided. Causative for not providing these information by the GVA Mödling was the matter of fact that this waste is not subject to be solely collected at ASZ.

Waste from biogenic origin has been identified as the major group that might be a result of the districts´ woodlot of 40% (Amt der NÖ Landesregierung, n.d.a) or the rural area in many municipalities. Fractions of street sweepings, “Baumix” and excavation waste may change during different time periods within the group of excavation/ construction waste (table 22, appendix) since these subfractions are usually only disposed during community projects (“Baumix”, excavation waste) or winter/ spring season (road cleanings), and are generally not dropped-off at the ASZ by residents (Tippel, 2014). However, it could not be excluded that the population disposed “Baumix” or excavation waste but amounts of these fractions were little compared to construction waste (that can be dropped off by any user), except for Maria Enzersdorf, Mödling and Perchtoldsdorf (table 22, appendix). Further it could not be figured out why street sweepings were only disposed in some municipalities but incomplete data might be reasonable.

Hazardous waste has been shown to be the smallest waste group with few amounts collected across different waste fractions but also the one with most of subfractions. However, it could be observed that only some fractions of hazardous waste, which differed between ASZ, were disposed (table 25-27, appendix). This might be explained by the fact that many critical substances do not usually occur in common households.

The MFA provided in this thesis has to be interpreted cautiously due to some assumptions that had to be made for fractions with more than one utilization method and thus actual numbers/ proportions of treatment methods may probably vary. This has to be considered in particular for hazardous waste where proportions for incineration (80%) and material recycling (20%) were assumed according to suggestions of the GVA Mödling (Tippel, 2014).

It is likely that proportions may differ since waste companies offer multiple treatment methods for the same subgroup and whether these hazardous fractions are incinerated or recycled depends on the market and the actual demand of material needed. This decision is made by the companies that utilize the waste, not by the GVA Mödling, and thus could not be traced back. Additionally, some companies distribute the waste to further enterprises that makes the assessment of actual allocation proportions even more difficult. Still, utilization rates for asbestos and synthetic/ polyacrylic/ polycarbonate waste reflect actual numbers since these problematic substances were exclusively utilized by one method (landfilling and material recycling, respectively).

It was also suggested to assume a 50/50 distribution for non-hazardous waste fractions (e.g. wood, waste wood, old tires, street sweepings) thus the actual flow rates remain uncertain with the EDM data provided. However, composting was probably the most common utilization method since the main input was received from garden/ green waste (more than 11.000 tons of all composted waste) and this fraction of the biogenic waste group was solely composted. This also applies for landfills because most waste originated from excavation waste (above 7.200 tons) and it may be assumed that actual numbers only slightly differ from these presented in the results. Regarding the process of incineration it can only be said that at least the flow of bulky waste is accurate (exclusively treated in incinerators). Rates for waste that was shredded (scrap metal), treated in refineries (edible oils/ fats) and EAG processing (WEEE) reflect either actual utilization rates since only one treatment method was applied.

4.2. Approach of Optimizing the Current Waste Management System

The density of ASZ in the district of Mödling (0.95 municipalities per ASZ) is much higher than the Austrian average (1.6 municipalities/ASZ) (Ehrengruber, 2010) which raised the question whether there is potential to improve the district´s waste collecting system in terms of efficiency and effectiveness but also considering the environmental consequences of such adaptations and the convenience for inhabitants in the area of interest. Thus, two simulations with 6.7 (scenario 1) and 1.4 municipalities per ASZ (scenario 2) had been introduced to assess differences in arising costs, environmental indicators as well as surrogates for the convenience of Mödling´s citizens. Analysis of data has revealed that the second simulation with 14 remaining ASZ appears to be more realizable than a scenario with only 3 ASZ due to a greater imbalance between user´s convenience, environmental impact and saving of expenses.

4.2.1 Geographical Distribution, ASZ Access & Environmental Indicators

It may be assumed that the geographical distribution as assessed for the status quo in this study might be acceptable for the district´s inhabitants because the maximal linear distance between ASZ and the corresponding inhabited area was measured to not exceed 7.8 km (Wienerwald). Considering the rate of motorization in the district of roughly 83% (Statistik Austria, 2013) it appears to be unlikely that this issue would affect the willingness of waste recycling in the district. However, road courses could not be assessed from the GIS data application and thus the exact distance for each household to their ASZ remains to be uncertain. These issues also apply for the simulations and as an expectable result of an ASZ reduction the individual distances increased for the majority of citizens and municipalities (scenario 1 > scenario 2) but they did not exceed the maximal measured distance of the status quo which was targeted for the simulations. However, for some areas in the district even a reduction in distance travelled was observed. This was to be achieved due to granting each citizen access to any ASZ within the simulations and the effect was more pronounced the higher the number of remaining ASZ (scenario 2). Based on these observations it would be reasonable to permit every household across the district - even in the present situation - admission to any ASZ. However, currently this is not feasible since inhabitants can only request a pass or card for permission (“Umweltkarte”, ”Bürgerkarte”) in the municipality of their registered residence (Tippel, 2014) (Guntramsdorf Marktgemeinde, n.d.) (Gemeinde Gaaden, 2012). This system appears to be logical for the individual municipalities that implemented it to avoid utilization costs for waste emerging from non-registered citizens and/ or forbidden waste dumping but it appears to remarkably affect the inhabitants´ daily life routine (e.g. incompatible opening hours, impossibility of waste disposal on the way home from work) due to confinement to one individual ASZ. Thus, a district wide solution of that issue should be sought to enhance both the convenience for the district´s citizens and perhaps even the waste collection system (e.g. increased collection rates due to better implementation of waste drop off in the daily routine).

As a result of increased travelled distances the annual diesel consumption and CO_2 emissions increased proportionally which appears to be unavoidable in finding an appropriate balance between justifiable environmental burdens, an efficiently/ effectively working waste collection system and a maximum degree of convenience for ASZ users. Considering the annual greenhouse gas emissions in Austria of approximately 80 million tons CO_2 equivalents (Das Umweltbundesamt, 2013) and although an increase in environmental indicators was detected (scenario 1 > scenario 2) they appear from an environmental point of view especially in the more realistic second scenario with a higher number of remaining ASZ and a change of +60.000 kg CO_2 to be acceptable and probably negligible.

4.2.2 Opening Hours and Operational Costs

It is likely that the ASZ opening hours are more important in terms of an effectively and efficiently working waste collection system than the ASZ locations or distances due to a vast density of ASZ across the district. The quantity of opening hours is dependent on the number of users of the respective ASZ and it is recommended that approximately 35% of these hours should be outside the normal working hours to increase the population´s convenience (Amt der NÖ Landesregierung, 2009). Standardized data of total waste collected across municipalities (table 9) may support the advice of population dependent operating hours since no clear trend between different opening hours (status quo) and the amount of waste disposed per inhabitant could be observed. This might demonstrate that less access to small ASZ do not affect the willingness of disposing waste.

Introduction of different simulations with opening hours according to minimum standards have shown that the present operating hours tremendously exceed these recommendations, which might indicate that there is an enormous potential for economic/ financial improvements. However, it has to be considered that it is common and recommended that ASZ are established at other local government facilities such as builder´s yards ("Bauhof") or landfills with already permanently appointed staff which might explain the extended opening hours in the present situation compared to minimum standards/ scenarios (Amt der NÖ Landesregierung, 2009) (Tippel, 2014). Thus, this study could only assess the maximum possible reduction in opening hours but the real extent – regardless, whether with or without a reduction of ASZ - remains uncertain.

This also applies for assessment of annually recurring operational (personnel + maintenance) costs that were calculated dependent on opening hours and indicates similar to operating hours the maximum possible savings. However, from an economic point of view (reduction of expenditures) a reevaluation of operating hours appear to be essential since they are more than 5-fold higher in the present situation than recommended according to minimum standards (in total approximately 3150 h for the entire district). Nevertheless, it has to be considered that cost calculations were based on recommendations (Amt der NÖ Landesregierung, 2011) due to a paucity of data provided by the GVA Mödling. Thus, the actual operational expenditures per hour could not be assessed and real figures may probably differ.

4.2.3 Investment Costs

This study shows that a smaller number of ASZ - leading to an increase of users per individual ASZ - results in a decline in investment costs in case that instead of 21 ASZ (status quo) only 3 (scenario 1) or 14 (scenario 2) would be newly established. However, it has to be taken into account that these costs are nonrecurring and that there are actual already 21 fully operating ASZ in the district available, thus results of calculated savings for different simulations have to be interpreted with caution and it is likely that by amalgamation of ASZ additional investment costs, instead of savings, would arise since adaptations of already operating ASZ for a higher waste turnover have to be made. This would further raise the question which municipalities should bear these extra expenditures because every citizen has permission to any ASZ (in simulated scenarios).

Assessment of arising investment expenditures were performed using recommendations from the ASZ guidelines (Amt der NÖ Landesregierung, 2009) due to a lack of economic data provided indicating that total investment costs across the district for the present situation may probably differ. Further, investment costs for the transfer station (MUM) could not be estimated for the status quo since cost assessment was based on an ASZ user dependent calculation indicating that total investment costs are likely to be even higher.

4.2.4 Expenditures for Citizens

As a result of the reduction in operating ASZ with an increase in distances to the ASZ the majority of the population in the area of interest would experience higher fuel costs and only some inhabitants would benefit from these adaptations. In consideration of the waste management levy (“Abfallwirtschaftsabgabe”) (GVA Mödling, n.d.c) (Der Gemeinderat der Stadtgemeinde Mödling, n.d.) that is much higher than the maximal annual additional fuel costs of +4.7 €/ year (Hennersdorf, scenario 1) and +0.8 €/ year (Wiener Neudorf, scenario 2) these increases seems to be affordable within this optimization process. Further, recent changes in the crude oil price that affect fuel prices have to be considered (Spritbarometer, n.d.). However, in addition to these expenditures extra drop-off fees for some waste fractions (tables 10 - 11) have to be taken into account but even these costs were calculated to be negligible in comparison to the announced levies (Der Gemeinderat der Stadtgemeinde Mödling, n.d.).

4.3. Brief Synopsis of Research Questions

To summarize the information gained by this thesis, brief replies to the research questions as stated in chapter 1.1. are provided in the following.

1. Is the current geographical distribution of the ASZ acceptable?
   Considering data from another federal state (Upper Austria) and Austria with higher rates of municipalities per ASZ (2.4 and 1.6, respectively) but increasing amounts of disposed waste over the past years (Ehrengruber, 2010) the distribution of Mödling´s ASZ (n=21) with 0.95 municipalities per ASZ is likely to be acceptable. The assessed short distances to the ASZ, in particular in the east of the investigated area, support this statement. However, these findings also illustrate that there might be potential for optimization in terms of an appropriate distribution of ASZ.
2. What might be an ideally acceptable distance among households and the recycling centers?
   The population was not actively involved (e.g. using questionnaires to assess reasons for attendance of an ASZ) in this study. Thus, it can only be hypothesized that assessed distances are acceptable for inhabitants but an "ideally acceptable distance" could not be obtained with the methodology used in this thesis. Taking into account the high motorization, waste disposal rates that seem to be independent of distances to the ASZ (table 7 and table 9) and an example from another district that merged ASZ (ASA, 2012), assessed distances to ASZ might not affect the willingness for waste disposal although shorter distances may be more convenient for the population.
3. Which type of waste is collected by each ASZ?
   Waste was categorized in 6 major groups: biogenic waste, excavation waste, scrap waste, bulky waste, waste electrical & electronical equipment and hazardous waste. These groups consist of a varying number of subfractions (figure 9, page 31). Although at each ASZ, except for the ASZ Münchendorf where no biogenic waste was dropped-off, any waste group was disposed, amounts within subfractions differed substantially among ASZ. This was particularly observed in the hazardous waste group.
4. How much waste is collected by each ASZ?
   The absolute numbers of total waste generated varied substantially among municipalities/ ASZ ranging from 297 – 6.914 tons/ year. Standardized data showed a more homogenous pattern with 150 - 621 kg/ inhabitant. This resulted in 35.307 tons/ year or 307 kg/ inhabitant of all waste collected for the entire district Mödling.

5. What are the methods employed for the collection and storage of waste?
   Storage options among ASZ are similar and only differ in size (e.g. containers) according to the capacity and needs of each facility. (Press) Containers, grid boxes, barrels, waste skips, unspecific storage areas and post pallets could have been identified as main collection and storage methods.
6. Are the employed methods well organized?
   On-site inspections showed that storage options are well organized (e.g. barrels for different hazardous waste fractions are all located at the same area) and local ASZ staff and signs support finding the desired location/ waste group.
7. Are the employed methods suitable for the storage, collection, transportation, processing and disposal of waste?
   Employed methods appear to be suitable for the entire recycling process. Each ASZ across the district use standardized storage/ collection methods (e.g. containers, waste skips) that can be easily transported by waste treatment operators. Further, for collection, transportation and processing of the waste sufficiently dimensioned entry roads are provided with adequate space to set down and empty containers.
8. How much was the investment cost of each ASZ?
   Investment costs for the present situation ranged from € 92.436 to € 471.740 (total: € 5.187.357) dependent on the number of user of each individual ASZ. In comparison to the status quo total estimated costs decreased by 72 % (- € 3.751.229) in scenario 1 and by 18% (- € 965.677) in scenario 2 for the entire district, respectively. However, by amalgamation of ASZ that would include adaptations of already operating ASZ for a higher waste turnover additional investment costs could arise. Thus, actual savings might probably be lower.
9. How much are the operational costs?
   Total operational costs for the present situation are € 1.007.930 (personnel costs) and € 368.317 (maintenance costs). In the simulations these costs decreased for the entire district by 93% (scenario 1) and by 85% (scenario 2) as compared to the present situation indicating savings of approximately € 1.280.000 in the first simulation and € 1.117.000 in second scenario, respectively.
10. How much are the extra drop-off fees for the customers?
    Annual extra charges appear to be rather low compared to the other costs as assessed in this thesis and were to be calculated by approximately € 70.000 for the entire district. It has to be noted that extra disposal fees only arise for some waste fractions (wood, construction waste, garden/ green waste, bulky waste, asbestos, old tires).

11. Are these fees too high?

    The assessed extra charges appear not to go beyond the population´s acceptance limit since only a small number of waste fractions are additionally charged and only when exceeding household amounts except for asbestos and old tires where every unit disposed has to be paid. Calculation of these costs has shown that only some households would pay extra charges. However, some (probably unrealistic) assumptions had to be made for cost assessment due to a paucity of data and inhabitants were not interviewed whether they would accept higher fees. It has to be considered that higher extra drop-off fees could discourage citizens to dispose their waste at ASZ.

12. Are these fees covering the operational cost for each ASZ?

    Although for cost calculation many assumptions had to be made it seems to be extremely unlikely that extra charges would cover the operational costs hence operational costs exceed the drop-off fees significantly. However, ASZ should not be aiming for covering arising costs (or even make profit) by charging their users any extra fees for waste disposal since the population is already obliged to pay waste management levies (“Abfallwirtschaftsabgabe”).

13. How can the ASZ be optimized in the view of economy and ecology?

    It has been shown that there might be an enormous potential for an economic optimization that is closely linked to a reevaluation of current opening hours since they highly exceed (minimum) recommendations and thus increase operational costs. Economic improvements might be further enhanced by an appropriate reduction of operating ASZ (see question 14) but it has to be taken into account that a lower number of ASZ might negatively impact the environment (increasing CO_2 emissions). From an ecologic point of view the current situation with rather short distances to the ASZ might be ideal due to lower greenhouse gas emissions in comparison to simulated scenarios. Considering these issues an appropriate waste management system should be both economically (e.g. number of ASZ, amount of opening hours) and ecologically (e.g. adequate emptying frequencies of storage methods, distances to ASZ) well balanced.

14. In particular, can the number of ASZ be reduced at the same degree of service for the communities involved, and are savings arising from such a reduced amount of ASZ?

    It is likely that a moderate reduction of ASZ (as presented in scenario 2) accompanied by permission to use any ASZ might not significantly affect the population´s convenience and would also lead to lower investment and operational costs. It has been shown that a reduced number of ASZ slightly increase travelled distances to ASZ and individual fuel costs but it is unlikely that these marginal changes have major impact on the users willingness to seek ASZ for waste disposal (see also research question 2). Further, an amalgamation process would induce a reduction of total opening hours across the entire district with a decrease particularly in operational costs. However, if these savings would be really that high as shown in this thesis remains uncertain since the maximal possible effect was assessed.

4.4. Summary and Recommendations

This study aimed to make the attempt to evaluate and optimize the present waste management system and to assess the impact on environmental and economic indicators as well as to determine possible changes in the population´s convenience.

It may be suggested that the current overall functioning of the ASZ in the district is highly efficient in terms of waste collection. As already presented in the results, the amount of waste disposed at each ASZ seems to be independent of the ASZ size. However, considering the GIS data (figure 8, status quo) it appears that ASZ, in particular in the district´s eastern half, are too tightly clustered. Taking into account that fixed costs such as land costs and operational costs put up roughly 70% of ASZ expenditures (Ehrengruber, 2010) it may be reasonable to reduce the high numbers of ASZ across the district in future projects since many ASZ are just some kilometers apart and to reorganize the current setting of one separate ASZ for each municipality with exclusive access only for the registered population of the respective municipality. This is supported by the introduced scenarios (with permission to use any ASZ) where despite an amalgamation of ASZ - especially in the second scenario with 14 remaining ASZ - probably acceptable changes in distances to ASZ, ecological indicators and fuel costs on the one hand and savings in operational and investment costs on the other hand could have been assessed. However, it has to be noted that data analysis was based on many assumptions due to a paucity of data provided and thus, real figures are likely subject to variations. The concept of amalgamation has already been employed in Styria (district Radkersburg) where 19 municipalities with previously separate ASZ were granted access to one central major ASZ (ASA, 2012). This was executed due to economic reasons and to keep current standards for waste disposal up to date in a more efficient way, which is easier to establish for a single ASZ than for many different (ASA, 2012).

The study could further show that estimated investment and operational costs exceed the extra drop-off fees significantly due to any additional charges for disposal of the majority of waste. The observed cost gap is consistent with information obtained from the GVA Mödling (Tippel, 2014) and is partly closed by the waste management levies ("Abfallwirtschaftsabgabe"), but real numbers were not provided and thus the actual difference remains to be uncertain. It is likely that the revenues from extra drop-off fees are higher since for this study it was assumed that each household only disposed exact one unit of chargeable waste, which appears to be unrealistic but was considered to be acceptable as calculation of these extra costs was highly hypothetically and thus, they were only assessed for the present situation and not for simulations since no major impact was to be expected. Asbestos (€ 6.450 for the entire district) is the only waste fraction that might represent real figures since it was independent from the number of households within municipalities and each unit had to be paid.

Based on the observations of this study it may be recommended that

- the population should receive for their convenience (e.g. more suitable opening hours, distances, etc.) access to any ASZ independent from an eventual ASZ amalgamation process as assessed in the simulations. However, it needs to be discussed who is going to bear the costs for e.g. waste utilization if citizens are allowed to use any ASZ.
- current opening hours should be reevaluated to lower operational costs. This should also be performed independently from a possible reduction in ASZ since operating hours highly exceed minimum recommendations, which indicates a profound potential for savings. Adaptations in opening hours should be made carefully and the user´s convenience should be considered.
- it should be avoided to be too restrictive with the number of operating ASZ (scenario 1) since environmental consequences and the population´s convenience might be affected in an improper way. In terms of user´s acceptance a district wide survey for assessment of reasons to use an ASZ/ dispose waste might be helpful.
- reorganizing the landscape of Mödling´s ASZ should be carried out stepwise and during a predefined observational period (e.g. one year) with subsequent analysis of EDM data and precise cost analysis. It may be useful to test this hypothesis initially in a small setting (e.g. replace 3 ASZ by one) and if this approach reveals to be financially efficient and accepted by the population - as a surrogate for acceptance unchanged or increased waste disposal rates would be expected - this concept could be extended to larger areas of the district. If such an optimization will be implemented it should be priory clarified who is going to bear additional (investment) costs.

5. Conclusion

The waste recycling centers play an important role in Austria to help meeting statutory recycling targets. Up until now, no studies have been published for the district of Mödling regarding the type and amount of waste collected, facilities and methods of collection, location and access, and whether the present waste collection system works properly. This study aimed to gain a better understanding of these issues by conducting a research to categorize and optimize waste collection centers in the district of Mödling, Lower Austria.

The introductory section gave an overview of the current situation of the waste management in Austria, Lower Austria, and the GVA Mödling. Consequently, the legal framework to show the political situation in Austria regarding ASZ and other relevant definitions such as efficiency and effectiveness were described. Thereby, norms, regulations and minimum standards linked to the practice of the waste collection centers were consulted to set major comprehension concerning the ASZ. The aim was to illustrate how the standards and legal aspects may contribute to the well functioning of the waste collection centers. The definitions of efficiency and effectiveness were used to assess on what degree the district has reached the established goals or not. Minimum standards and regulations are being implemented in accordance to the legal framework.

In the second chapter, materials and methods to assess the study objectives were described. Data of 2013 were provided and interviews were conducted with an expert of the GVA Mödling and with stakeholders of the waste management association, which contributed enormously to the overall development of this thesis. The data provided was adjusted to the number of inhabitants of each municipality in order to assess a potential effect of the population size on the total amounts of disposed waste across municipalities. Population data was provided from the year of 2013 and only household waste disposed at any ASZ across the district was considered for this study. The geographical distribution was evaluated by assessment of geographic information system data to exactly locate the ASZ on the map. Material flow analysis was used to analyze the amount of waste collected and utilized across the district. For assessment of potential improvements of the waste management system two different scenarios with a reduced number of ASZ were introduced to assess environmental indicators, economic data and the population´s convenience.

However, several assumptions had to be made due to a paucity of data. First, for the material flow analysis, for some waste fractions the allocation to the applied utilization methods with two different possible options had to be estimated. Secondly, calculations for investment and operational costs were based on recommendations of guidelines since no exact data could have been obtained by the GVA Mödling.

The third chapter summarizes the results of this study and it has been shown that the amount of total waste collected across municipalities appears to independent of the ASZ size due to no clear trend in waste disposal rates among different sized ASZ. Biogenic waste represents the largest waste group disposed and MFA revealed that most of all waste is utilized by composting. Introduction of scenarios and comparison with the status quo has shown, that adjusting the rate of municipalities per ASZ closer to the Austrian average (scenario 2) might be acceptable for both the populations convenience and environmental consequences. The simulations also detected that the quantity of present ASZ opening hours highly exceed recommended minimums standards and thus, might have great potential for financial savings. However, these (extended) opening hours might contribute that the current waste disposing process works efficiently and it remains unclear if less operating hours would not negatively influence the willingness to drop off waste.

In conclusion, to exactly assess the actual reasons for the population of the district Mödling to dispose waste at the ASZ or not, the only reliable tool might be the conduct of a survey which could also figure out if items investigated in this thesis such as the location of the ASZ or the distance to them really affect the willingness to seek a waste collection center. Additionally, it is likely that there is a potential for an optimization in terms of the number of operating ASZ across the district, which would probably further lead to financial savings. However, more precise and actual data (e.g. for investment or operational costs) would have been required to verify if the conclusions drawn in this thesis are actually valid but the results may serve as a guide for future studies (e.g. merging of ASZ to reduce fixed costs) to improve the management of the waste collection centers.

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Appendix

GEMEINDEVERBAND FÜR ABGABENEINHEBUNG UND UMWELTSCHUTZ IM BEZIRK MÖDLING

Kampstraße 1
2344 Maria Enzersdorf
02236/73940-0
02236/73940-16
office@gvamoedling.at
http://www.abfallverband.at/moedling

E N T S O R G U N G S T A R I F E
Altstoffsammelzentrum Gemeinde ....
20.09.2011
(Sämtliche Preise in € inklusive 10 % Umsatzsteuer)

Baum- und Strauchschnitt:	
Eine Haushaltsmenge	kostenlos
Pro zusätzlicher Haushaltsmenge	12,-
Bauschutt:	
Eine Kleinmenge	kostenlos
Pro zusätzlicher Kleinmenge	15,-
Asbest:	
Eine Kleinmenge	25,-
Grünschnitt:	
Eine Haushaltsmenge	kostenlos
Pro zusätzlicher Haushaltsmenge	16,-
Reifen:	
Reifen mit Felge pro Stück	2,50
Reifen ohne Felge pro Stück	1,-
Traktor-/LKW Reifen pro Stück	15,-
Sperrmüll:	
Eine Haushaltsmenge	kostenlos
Pro zusätzlicher Haushaltsmenge	25,-
Wurzelstöcke:	
Durchmesser 30 – 50 cm pro Stück	20,-
Durchmesser 50 – 80 cm pro Stück	50,-
Abholungen ab Haus (Gehsteigkante) von z.B. Sperrmüll, Grünschnitt nach Terminvereinbarung (einmal pro Jahr):	35,-

Definitionen:
Kleinmenge .... ein kleiner Anhänger (1 x 1 m ohne Aufbau) bzw. ein Kofferraum bzw. 2 Schiebetruhen bzw. max. ½ m³

Haushaltsmenge .... Bis zu 2 m³

Bankverbindung Raiffeisen Regionalbank Mödling, Kontonr.: 1.615.707, BLZ 32250

\\GVASERVER\ODat\Gebührenhoheit\GVA_Vorlagen_GVA\Abfall\Entsorgungstarife_ASZ_101027.doc

So macht Abfallwirtschaft Sinn. die niederösterreichischen ABFALLverbände

Figure 20. – Recommended disposal fees by the GVA Mödling for ASZ in the district of Mödling

Table 21. – Longitude and Latitude of the ASZ in the corresponding municipalities according to their postal addresses (GVA Mödling, n.d.b) (Google, n.d.).

Municipality	**Longitude**	**Latitude**
Achau	16.386437	48.080493
Biedermannsdorf	16.356367	48.090565
Breitenfurt b. Wien	16.184207	48.135308
Brunn a. Gebirge	16.303361	48.111332
Gaaden	16.215829	48.067841
Gießhübl	16.236435	48.094712
Gumpoldskirchen	16.289754	48.035988
Guntramsdorf	16.333759	48.043122
Hennersdorf	16.365479	48.111306
Hinterbrühl	16.195410	48.070627
Kaltenleutgeben	16.160344	48.110898
Laab im Walde	16.166175	48.154418
Laxenburg	16.354706	48.069500
Maria Enzersdorf	16.292623	48.094020
Mödling	16.298331	48.078764
Münchendorf	16.385105	48.022160
Perchtoldsdorf	16.28324	48.116283
Vösendorf	16.360898	48.118662
Wiener Neudorf	16.328356	48.084488
Wienerwald	16.168777	48.067489
MUM	16.310312	48.064661

Table 22. – Amount of collected bulky waste, biogenic waste and excavation/ construction waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	Bulky Waste tons | [kg/inhabitant]	Biogenic waste tons | [kg/inhabitant]		Excavation/ construction waste tons | [kg/inhabitant]			
	Bulky waste	Garden/green waste	Wood (trees and bushes)	Construction waste	Excavation waste	Baumix	Street-sweepings
Achau	48.0 [39]	112.8 [91]	31.8 [26]	46.9 [38]	0 [0]	0 [0]	0 [0]
Biedermannsdorf	91.2 [32]	104.0 [37]	187.5 [66]	196.1 [69]	0 [0]	0 [0]	10.0 [4]
Breitenfurt b. Wien	348.2 [60]	420.0 [72]	1980.0 [341]	240.9 [41]	0 [0]	0 [0]	0 [0]
Brunn a. Gebirge	524.6 [46]	3016.3 [265]	673.0 [59]	1624.0 [143]	0 [0]	0 [0]	490.6 [43]
Gaaden	93.8 [59]	480.0 [300]	126.0 [79]	145.1 [91]	0 [0]	0 [0]	0 [0]
Gießhübl	75.7 [34]	304.5 [139]	0 [0]	67.0 [31]	0 [0]	4.0 [2]	24.0 [11]
Gumpoldskirchen	145.9 [40]	0 [0]	379.4 [104]	503.1 [137]	0 [0]	0 [0]	0 [0]
Guntramsdorf	196.6 [22]	578.2 [64]	0 [0]	335.8 [37]	0 [0]	0 [0]	0 [0]
Hennersdorf	61.9 [44]	161.2 [114]	0 [0]	88.0 [62]	0 [0]	0 [0]	0 [0]
Hinterbrühl	97.7 [24]	340.0 [84]	0 [0]	113.7 [28]	0 [0]	0 [0]	0 [0]
Kaltenleutgeben	183.9 [55]	138.2 [41]	68.6 [21]	206.6 [62]	0 [0]	0 [0]	0 [0]
Laab im Walde	76.6 [66]	75.0 [65]	0 [0]	63.4 [55]	0 [0]	0 [0]	0 [0]
Laxenburg	65.0 [23]	558.0 [198]	307.0 [109]	98.4 [35]	0 [0]	0 [0]	0 [0]
Maria Enzersdorf	277.2 [32]	808.1 [93]	301.5 [35]	484.8 [56]	287.6 [33]	0 [0]	0 [0]
Mödling	642.0 [31]	1039.1 [51]	0 [0]	508.4 [25]	13.1 [1]	136.2 [7]	874.7 [43]
Münchendorf	115.5 [42]	0 [0]	0 [0]	134.5 [49]	0 [0]	0 [0]	0 [0]
Perchtoldsdorf	472.8 [32]	1743.1 [119]	0 [0]	894.5 [61]	364.4 [25]	0 [0]	0 [0]
Vösendorf	372.5 [57]	865.6 [133]	0 [0]	633.6 [97]	0 [0]	0 [0]	0 [0]
Wiener Neudorf	487.0 [55]	301.6 [34]	301.6 [34]	751.0 [85]	0 [0]	0 [0]	0 [0]
Wienerwald	161.6 [65]	0 [0]	109.3 [44]	155.1 [62]	54.4 [22]	0 [0]	0 [0]
District Mödling	**4537.1 [40]**	**11045.8 [96]**	**4465.6 [39]**	**7290.8 [63]**	**719.5 [6]**	**140.2 [1]**	**1399.3 [12]**

Table 23. – Amount of collected scrap waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling , 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	**Scrap waste tons | [kg/inhabitant]**					
	Cardboard	Scrap metal	Used textiles	Edible oils/fats	Waste wood	Old tires
Achau	18.9 [15]	0 [0]	6.1 [5]	1.9 [1]	31.8 [26]	1.1 [1]
Biedermannsdorf	21.2 [7]	44.0 [16]	15.5 [5]	1.5 [1]	118.4 [42]	1.0 [<1]
Breitenfurt b. Wien	41.7 [7]	30.0 [5]	39.2 [7]	4.0 [1]	233.8 [40]	2.2 [<1]
Brunn a. Gebirge	36.9 [3]	104.8 [9]	1.0 [0]	2.9 [<1]	320.6 [28]	6.6 [1]
Gaaden	31.1 [19]	16.8 [11]	5.5 [3]	2.4 [2]	74.7 [47]	1.0 [1]
Gießhübl	17.8 [8]	9.3 [4]	9.5 [4]	1.2 [1]	61.2 [28]	0.5 [<1]
Gumpoldskirchen	78.8 [22]	68.9 [19]	15.7 [4]	3.9 [1]	134.3 [37]	2.7 [1]
Guntramsdorf	37.1 [4]	30.6 [3]	23.1 [3]	4.8 [1]	248.4 [28]	1.5 [<1]
Hennersdorf	29.8 [21]	2.1 [1]	9.9 [7]	4.1 [3]	59.4 [42]	0.7 [<1]
Hinterbrühl	19.6 [5]	8.9 [2]	10.9 [3]	1.3 [<1]	78.4 [19]	1.5 [<1]
Kaltenleutgeben	16.6 [5]	54.8 [16]	20.9 [6]	1.8 [1]	127.9 [38]	3.0 [1]
Laab im Walde	12.6 [11]	16.8 [15]	6.0 [5]	1.1 [1]	32.9 [29]	0.2 [<1]
Laxenburg	49.0 [17]	18.4 [7]	14.1 [5]	1.4 [<1]	61.8 [22]	0.4 [<1]
Maria Enzersdorf	31.0 [4]	36.9 [4]	3.9 [<1]	3.5 [<1]	203.0 [23]	1.8 [<1]
Mödling	48.1 [2]	94.9 [5]	16.7 [1]	5.5 [<1]	127.8 [6]	11.6 [1]
Münchendorf	13.7 [5]	0 [0]	15.0 [5]	2.4 [1]	88.6 [32]	3.1 [1]
Perchtoldsdorf	91.0 [6]	171.9 [12]	9.6 [1]	5.9 [<1]	465.6 [32]	5.0 [<1]
Vösendorf	0 [0]	42.7 [7]	19.3 [3]	2.6 [<1]	1855 [28]	5.0 [1]
Wiener Neudorf	15.1 [2]	0 [0]	19.8 [2]	6.3 [1]	113.9 [13]	0 [0]
Wienerwald	9.3 [4]	39.5 [16]	11.6 [5]	2.2 [1]	88.2 [35]	3.5 [1]
District Mödling	**619.1 [5]**	**791.3 [7]**	**273.0 [2]**	**60.6 [1]**	**2856.1 [25]**	**52.4 [<1]**

Table 24. – Amount of collected electrical and electronic equipment waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling , 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	**Waste electrical and electronic equipment (WEEE) tons | [kg/inhabitant]**				
	Cooling appliances	Display screen equipment	Large electrical appliances	Small electrical appliances	Fluorescent tubes
Achau	1.2 [1]	1.5 [1]	0.9 [1]	2.5 [2]	0.1 [<1]
Biedermannsdorf	2.0 [1]	6.7 [1]	3.3 [1]	4.2 [1]	0.4 [<1]
Breitenfurt b. Wien	4.5 [1]	7.4 [1]	5.1 [1]	12.8 [2]	0.2 [<1]
Brunn a. Gebirge	9.0 [1]	14.8 [1]	16.5 [1]	24.3 [2]	0.7 [<1]
Gaaden	1.9 [1]	2.7 [1]	2.7 [2]	5.1 [3]	0 [0]
Gießhübl	1.4 [1]	2.7 [1]	3.7 [2]	3.9 [2]	0.1 [<1]
Gumpoldskirchen	4.3.[1]	6.3 [1]	17.1 [5]	10.2 [3]	0.1 [<1]
Guntramsdorf	8.7[1]	13.8 [1]	16.9 [2]	17.0 [2]	0.4 [<1]
Hennersdorf	1.6 [1]	2.6 [1]	0 [0]	3.9 [3]	0.1 [<1]
Hinterbrühl	2.0 [<1]	4.2 [<1]	0.1 [<1]	5.4 [1]	0.1 [<1]
Kaltenleutgeben	3.3 [1]	5.1 [1]	2.6 [1]	6.2 [2]	0.1 [<1]
Laab im Walde	1.1 [1]	1.7 [1]	0 [0]	1.9 [2]	0 [0]
Laxenburg	1.2 [<1]	1.9 [<1]	3.2 [1]	6.4 [2]	0.1 [<1]
Maria Enzersdorf	4.9 [1]	11.7 [1]	1.5 [<1]	14.4 [2]	0.8 [<1]
Mödling	17.3 [1]	30.8 [1]	38.9 [2]	36.1 [2]	1.3 [<1]
Münchendorf	1.9 [1]	3.5 [1]	0.7 [<1]	6.1 [2]	0.4 [<1]
Perchtoldsdorf	11.9 [1]	19.9 [1]	14.2 [1]	29.1 [2]	0.6 [<1]
Vösendorf	6.9 [1]	8.1 [1]	20.6 [3]	8.4 [1]	0.4 [<1]
Wiener Neudorf	7.6 [1]	13.3 [1]	15.3 [2]	14.5 [2]	0.4 [<1]
Wienerwald	2.4 [1]	3.6 [1]	3.4 [1]	4.4 [2]	0.2 [<1]
District Mödling	**95.1 [1]**	**162.3 [1]**	**166.6 [1]**	**217.0 [2]**	**6.5 [<1]**

Table 25. – Amount of collected hazardous waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling , 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	**Hazardous waste (problematic substances) tons | [kg/inhabitant]**								
	Waste oil	Oil-containing waste/ Factory waste	Waste paint/ Paint residues	Pesticides/ Poisonous substances	Acids	Leachate	Pressure vessels/ Spray cans	Expired medications	Non-sorted batteries
Achau	0.2 [<1]	0.1 [<1]	2.8 [2]	0.1 [<1]	0 [0]	0 [0]	0.2 [<1]	0.1 [<1]	0.3 [<1]
Biedermannsdorf	0.6 [<1]	1.0 [<1]	8.1 [3]	0 [0]	0 [0]	0 [0]	0.2 [<1]	0.6 [<1]	1.3 [<1]
Breitenfurt b. Wien	2.9 [<1]	2.0 [<1]	9.6 [2]	0.1 [<1]	0 [0]	0 [0]	0.8 [<1]	0.9 [<1]	1.4 [<1]
Brunn a. Gebirge	2.0 [<1]	1.0 [<1]	10.5 [1]	0 [6]	0 [0]	0 [0]	0.7 [<1]	1.2 [<1]	1.1 [<1]
Gaaden	1.2 [1]	0.1 [<1]	2.2 [1]	0.1 [<1]	0 [0]	0 [0]	0.1 [<1]	0.1 [<1]	0.3 [<1]
Gießhübl	0.4 [<1]	0.2 [<1]	4.2 [2]	0 [6]	0 [0]	0 [0]	0.2 [<1]	0.2 [<1]	0.3 [<1]
Gumpoldskirchen	1.1 [<1]	0.2 [<1]	8.2[2]	0.2 [<1]	0 [0]	0 [0]	0.4 [<1]	0.2 [<1]	0.5 [<1]
Guntramsdorf	1.7 [<1]	0.4 [<1]	4.2 [<1]	0.1 [<1]	0 [0]	0 [0]	0.5 [<1]	1.4 [<1]	0.8 [<1]
Hennersdorf	0.9 [1]	0.2 [<1]	3.9 [3]	0.1 [<1]	0 [0]	0 [0]	0.3 [<1]	0.1 [<1]	0.2 [<1]
Hinterbrühl	0.1 [<1]	0.2 [<1]	1.7 [<1]	0 [0]	0 [0]	0 [0]	0.3 [<1]	0.6 [<1]	0.3 [<1]
Kaltenleutgeben	0.8 [<1]	0.1 [<1]	5.7 [2]	0.1 [<1]	0.1 [<1]	0 [0]	0.4 [<1]	0.4 [<1]	0.3 [<1]
Laab im Walde	0.6 [1]	0 [0]	2.5[2]	0 [0]	0 [0]	0 [0]	0.2 [<1]	0 [0]	0.1 [<1]
Laxenburg	0.3 [<1]	0.8 [<1]	4.1 [1]	0.1 [<1]	0 [0]	0 [0]	0.3 [<1]	0.5 [<1]	0.3 [<1]
Maria Enzersdorf	1.6 [<1]	1.0 [<1]	10.3 [1]	0.5 [<1]	0.1 [<1]	0.1 [<1]	0.5 [<1]	1.6 [<1]	1.1 [<1]
Mödling	3.8 [<1]	1.0 [<1]	19.6 [1]	0.4 [<1]	0 [0]	0 [0]	1.0 [<1]	1.9 [<1]	0 [0]
Münchendorf	2.5 [1]	1.0 [<1]	9.3 [3]	0.7 [<1]	0 [0]	0 [0]	0.3 [<1]	0.2 [<1]	0.4 [<1]
Perchtoldsdorf	2.5 [<1]	1.8 [<1]	21.8 [1]	0.5 [<1]	0.1 [<1]	0 [0]	1.6 [<1]	2.8 [<1]	1.8 [<1]
Vösendorf	1.8 [<1]	1.7 [<1]	8.4 [1]	0 [0]	0 [0]	0 [0]	0.6 [<1]	0.1 [<1]	1.3 [<1]
Wiener Neudorf	1.5 [<1]	0.9 [<1]	3.0 [<1]	0.3 [<1]	0.1 [<1]	0 [0]	0.5 [<1]	0.5 [<1]	0.8 [<1]
Wienerwald	1.7 [1]	0.8 [<1]	4.5 [2]	0.1 [<1]	0 [0]	0 [0]	0.2 [<1]	0.1 [<1]	0.4 [<1]
District Mödling	**28.4 [<1]**	**14.4 [<1]**	**144.7 [1]**	**3.3 [<1]**	**0.4 [<1]**	**0.1 [<1]**	**9.4 [<1]**	**13.5 [<1]**	**12.9 [<1]**

Table 26. – Amount of collected hazardous waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling , 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	Hazardous waste (problematic substances) tons | [kg/inhabitant]								
	Lead accumulators	Solvents	Laboratory waste/ Chemicals residues	Wrecked cars	Electrolytic capacitors	Fire extinguishers	Overlaid Toiletry	Fuels	Ink residues/ Copier toners
Achau	0.6 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0 [0]
Biedermannsdorf	0 [0]	0.2 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Breitenfurt b. Wien	1.6 [<1]	0 [0]	2.0 [<1]	0 [0]	0 [0]	0.3 [<1]	0.2 [<1]	0.2 [<1]	0 [0]
Brunn a. Gebirge	2.2 [<1]	0 [0]	0.8 [<1]	0 [0]	0 [0]	0.6 [<1]	0 [0]	0 [0]	0 [0]
Gaaden	0 [0]	0 [0]	0.4 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Gießhübl	0.6 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Gumpoldskirchen	0.6 [<1]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0 [0]
Guntramsdorf	2.1 [<1]	0.1 [<1]	0.9 [<1]	0 [0]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0.1 [<1]
Hennersdorf	0.8 [1]	0 [0]	0.9 [1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Hinterbrühl	0.2 [<1]	0 [0]	0.5 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Kaltenleutgeben	1.7 [1]	0.4 [<1]	0.2 [<1]	7.0 [2]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Laab im Walde	0 [0]	0.1 [<1]	0.3 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Laxenburg	0 [0]	0.2 [<1]	0.4 [<1]	0 [0]	0 [0]	0 [0]	0.2 [<1]	0 [0]	0 [0]
Maria Enzersdorf	0 [0]	0.6 [<1]	0.5 [<1]	0 [0]	0 [0]	0.3 [<1]	0 [0]	0 [0]	0 [0]
Mödling	5.1 [<1]	1.2 [<1]	2.5 [<1]	0 [0]	0 [0]	0.2 [<1]	0 [0]	0 [0]	0 [0]
Münchendorf	0 [0]	0 [0]	0 [0]	0 [0]	0.1 [<1]	0.1 [<1]	0 [0]	0 [0]	0 [0]
Perchtoldsdorf	0.8 [<1]	0 [0]	4.3 [<1]	6.0 [<1]	0.1 [<1]	2.0 [<1]	0 [0]	0.2 [<1]	0 [0]
Vösendorf	0.8 [<1]	1.0 [<1]	0.6 [<1]	1.7 [<1]	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]
Wiener Neudorf	3.3 [<1]	1.4 [<1]	0.4 [<1]	0 [0]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0 [0]
Wienerwald	0.7 [<1]	0.4 [<1]	0.4 [<1]	0 [0]	0 [0]	0.1 [<1]	0 [0]	0.2 [<1]	0 [0]
District Mödling	**21.0 [<1]**	**5.7 [<1]**	**15.1 [<1]**	**14.7 [<1]**	**0.2 [<1]**	**3.8 [<1]**	**0.4 [<1]**	**0.6 [<1]**	**0.1 [<1]**

Table 27. – Amount of collected hazardous waste at the waste collection centres of each municipality of the district Mödling and the total collected volume in the district according to EDM data (GVA Mödling , 2013). Data is presented in tons and standardized to the individual municipality´s/ district´s population in [kg per inhabitant].

Municipality	**Hazardous waste (problematic substances) tons | [kg/inhabitant]**								
	Glue/ not hardened adhesives	Glue/ hardened adhesives	Synthetic/ Polyacrylic/ polycarbonate waste (CDs)	Wastebased synthetics dispersion	Gasses in stamping bottles	Syringes and other pointed or sharp objects	Asbestos	Liquid mercury	Film/ Celluloid/ X-ray films waste
Achau	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	0 [0]	<0.1 [<1]	0 [0]
Biedermannsdorf	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	0 [0]	0 [0]	0 [0]
Breitenfurt b. Wien	0 [0]	0 [0]	0 [0]	0 [0]	0.2 [<1]	0	10.0 [2]	0 [0]	0 [0]
Brunn a. Gebirge	0 [0]	0 [0]	0.1 [<1]	10.4 [1]	0.1 [<1]	0.1 [<1]	16.9 [1]	0 [0]	0 [0]
Gaaden	0 [0]	0 [0]	0 [0]	0.2 [<1]	0 [0]	0	0 [0]	0 [0]	0 [0]
Gießhübl	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	4.1 [2]	0 [0]	0 [0]
Gumpoldskirchen	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	11.5 [3]	<0.1 [<1]	0 [0]
Guntramsdorf	0 [0]	0 [0]	0.1 [<1]	6.0 [1]	0 [0]	0	5.6 [1]	0 [0]	0 [0]
Hennersdorf	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	0 [0]	0 [0]	0 [0]
Hinterbrühl	0 [0]	0 [0]	0 [0]	2.3 [1]	0 [0]	0	2.7 [1]	0 [0]	0 [0]
Kaltenleutgeben	0 [0]	0 [0]	0 [0]	0 [0]	0.1 [<1]	0	5.4 [2]	0 [0]	0 [0]
Laab im Walde	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	3.7 [3]	0 [0]	0 [0]
Laxenburg	0 [0]	0 [0]	0.1 [<1]	0 [0]	0 [0]	0	2.7 [1]	0 [0]	0 [0]
Maria Enzersdorf	0 [0]	0 [0]	0.1 [<1]	0 [0]	0.2 [<1]	0	7.0 [1]	<0.1 [<1]	0 [0]
Mödling	0 [0]	0 [0]	0 [0]	0.7 [<1]	0.1 [<1]	0.3 [<1]	0 [0]	0 [0]	0 [0]
Münchendorf	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	9.0 [3]	0 [0]	0 [0]
Perchtoldsdorf	0 [0]	0 [0]	0 [0]	0 [0]	0.3 [<1]	0.2 [<1]	4.9 [<1]	0 [0]	0 [0]
Vösendorf	0.1 [<1]	0.1 [<1]	0.2 [<1]	0.2 [<1]	0 [0]	0.1 [<1]	0 [0]	0 [0]	<0.1 [<1]
Wiener Neudorf	0 [0]	0 [0]	0 [0]	8.5 [1]	0 [0]	0	0 [0]	0 [0]	0 [0]
Wienerwald	0 [0]	0 [0]	0 [0]	0 [0]	0 [0]	0	4.9 [2]	0 [0]	0 [0]
District Mödling	**0.1 [<1]**	**0.1 [<1]**	**0.6 [<1]**	**28.3 [<1]**	**1.0 [<1]**	**0.8 [<1]**	**88.4 [1]**	**<0.1 [<1]**	**<0.1 [<1]**