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MSc Program
Environmental Technology & International Affairs

Sinks as Constraints for Urban Development? Analysis of the flows of goods of a typical Viennese household into the sinks according to the four main activities

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

supervised by
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Vienna, October 20, 2011

Affidavit

I, **I-HSIEN CHEN**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Sinks as Constraints for Urban Development? Analysis of the flows of goods of a typical Viennese household into the sinks according to the four main activities.", 49 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 not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 20.10.2011

____
Signature

Acknowledgement

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And finally, Agnes for her understanding.

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Glossary of Terms

MA 22	MD for Environmental Protection
MA 28	MD for Road Construction and Maintenance
MA 29	MD for Bridges
MA 48	MD for Waste Management
MA	“Magistratsabteilung” = Municipal Department (MD)
MFA	Material Flow Analysis
ÖSTAT	“Statistik Austria” = Austrian Statistical Bureau
PHH	Private Household
VWMA	Vienna Waste Management Authority same as MA 48
WWTP	Waste Water Treatment Plant

0 Abstract

This paper aims at matching the different input flow of goods into an average Private Household with other (not directly to the input flows linkable) output flows into the sinks according to the four activities *To Nourish*, *To Clean, To Reside* and *To Transport and Communicate*, as well as taking into account the stock of the four activities in Vienna, and undertake to describe and explain these flow as a basis for further studies.

To match the input flows with the output flows, different sources were compared, weighed and interpreted for its quality, intention and origin.

For the calculation of the flows, it has been important to take a detailed analysis of the stock and their composition, which has been one of the most important and difficult undertakings, e.g. to estimate the numbers of electronic equipment still stocked in Vienna or the material composition of the Vienna buildings infrastructure, which can be several hundred years old etc.

Vienna with about 1,7 mio. inhabitants is a fast growing city (10% in the last decade) and understanding the limitations that sinks can present to further sustainable growth by looking purely at the quantitative mass flows and stocks – attributed to the activities - can give valuable information for further studies on these relationships, as well as comparing them with qualitative approaches.

As a methodology, the Material Flow Analysis has been applied, an as a tool, the STAN Software was utilized.

To summarize, the activity *To Reside* showed the highest stock with 142 t/c, with a input of 6,9 t/c.a and 5,9 t/c.a output, thus resulting in a yearly growth of 1 t/c.a. On the other hand, the activity *To Clean* showed the highest flow with 46,8 t/c.a, with more than 99% of this flow consisting of water.

For the activity *To Nourish* with 8,3t/c.a, the highest flow (80%) consists of air. For the activity *To Transport and Communicate,* the input of 4,2 t/c.a stock and 4,1 t/c.a tons of output is evenly divided between the various input factors.

As a result, speaking from a pure quantitative standpoint, the issue of construction waste is shown as the most probable limitation, as the Vienna sinks can only hold about one year's volume of construction waste, whereas the sinks water and air seem unproblematic.

However, as noted before, these quantitative results need to be further complemented by qualitative studies or analysis of flows of specific problematic goods, which may add many more limitations to further growth of the city of Vienna posed by its sinks.

1 Introduction

1.1 Research Aim and Question

Within the project Sinks as Constraints for Urban Development (SCUDE) this paper aims at analysing the flows of goods of an average private household into the sinks within the boundary of Vienna according to the four main activities:

- To Nourish
- To Clean
- To Reside
- To Transport and Communicate

The aim of this study is to match and compare the inflows of goods into the PHH with the corresponding exports and outflows into the sinks.

The Private Household (PHH) is one of the main subsystems of urban regions, its transformation of goods into offgas, waste water and waste into the temporary and final sinks are an important parameter and indicator for the capability for the sustainability and growth of a city.

Within a larger framework, it would be very interesting to compare the data between Vienna and other comparable cities and with quantitative approaches. This, however, lies beyond this thesis.

1.2 General Approach

The research started with the collection of the available data and the definition of a target year for all data being calculated for the reference year 2008. The selection was founded on the basis that data shall be available but as recent as possible. If the data was not available for this reference year, an estimate would be used according to the last available data. On the other hand, if even newer data is available, the data of the reference year will be preferred.

2 Research Methodology

2.1 *Methodology*

As a Methodology, the method for the analysis of Material fluxes or Material Flow Analysis (MFA) developed by Baccini and Brunner (1991), and further described by Brunner and Rechberger 2004 has been applied.

As for the definition of activities and processes and attribution of goods to these processes and activities I have used the system used in the study Baccini and Brunner (1991), the METAPOLIS study from Baccini et al. (1993) in Switzerland and also referred to the pre-cursing Master Thesis of Beschorner (1996).

For the measurement of the flows, kilogram per capita and year (annum) [kg/c·a] or [kg/c·a] is used, and [kg/c] or tons per capita [t/c] is used for the stock.

The flow of goods into the private household is analysed according the four activities *To Clean*, *To Nourish*, *To Reside* and *To Transport and Communicate*.

2.2 *MFA Terms and Definitions*

The terms and definitions of the MFA follows Brunner/Rechberger (2004: 36ff), where the flow of goods into the private household is analysed according the four activities *To Clean, To Nourish, To Reside* and *To Transport and Communicate*.

2.2.1 Substances

Within the MFA, “substances” are defined by chemical science, as a chemical element or compound composed of uniform units, and are characterized by a unique and identical constitution and are therefore homogenous. Thus, elements such as carbon (C) or oxygen (O) are substances as well as compounds such as ammonia (NH_3) or methane (CH_4). Wood on the other hand, can be composed of many different substances in different concentrations it is not homogeneous and therefore not a substance.

2.2.2 Goods

Goods are defined as economic entities of matter with a positive or negative economic value. Goods are made up of several substances. Examples for goods in the private households with positive economic value are drinking water, concrete, cars, etc. with negative economic values are garbage, sewage sludge etc.

2.2.3 Material

In the context of MFA, "material" is used as an umbrella term for both substances and goods.

2.2.4 Process

A Process is defined as the transformation, transport, or storage of materials. Consumption processes take place in the private household, where goods are transformed into wastes and emissions. Examples for the private households would be: Human Body – food, water, air transformed into offgas, urine, feces… or where the inputs of goods of a private household is transformed into sewage, wastes, emissions and some useful recyclable outputs.

Flow and Flux

A Flow is defined as a "Mass Flow Rate". This is the ratio of mass per time that flows through e.g. a water pipe, e.g. kg/sec, l/sec or t/year. A Flux is defined as a flow per "cross section". For the water pipe, that means that the flow is related to the cross section of the pipe, the flux might then be given in units of l/sec•m^2. The flux can be considered as specific flow.

2.2.5 System and system Boundary

The system, in our case the private households in Vienna, is the actual object of an MFA investigation. The System boundaries are defined in time and space, time is the year 2008 and space is all private households in the city boundaries of the city of Vienna

2.2.6 Activities

Goods and services can be part of several activities, e.g. the car can be part of the activity *To Reside* but also of the activity *To Transport*. There are no rules regarding the linkage of processes to activities, this paper relies mostly on the linkage provided by the comprehensive study *Metapolis* from Baccini et al. (1993).

2.2.6.1 To Nourish

This activity consists of all processes, goods and substances to produce, process, distribute and consume solid and liquid food. For the private households in Vienna, only the processes within the private households are considered.

2.2.6.2 To Clean

In anthropogenic processes, “wanted” materials are separated from “unwanted” materials. In the case of the private households in Vienna, the separation of valuable from useless materials has been defined as the activity “To Clean”, especially laundry, dish washing, hygiene, laundry etc.

2.2.6.3 To Reside

This activity consists of all processes that are necessary to build, operate and maintain residential buildings, furnishing, but also cooling and heating.

2.2.6.4 To Transport and Communicate

For the PHH all processes that transport persons and information are considered. The processes and goods that are associated with this activity have undergone the most rapid transformation of all activities, with the rise of telecommunication infrastructure being a very new and important part of this activity.

2.3 Previous Studies on this topic

This thesis relies in its methodology and base assumptions on the already mentioned Metapolis Study from Baccini et al. (1993) and the Master
Thesis of Beschorner (1996).

The four activities are subdivided into the main processes within each activity with the largest flow of goods in terms of quantity (not quality).

Goods, which could not be attributed to one of the four activities were summarised under the category of "other". Immobile goods and building structures were attributed per capita.

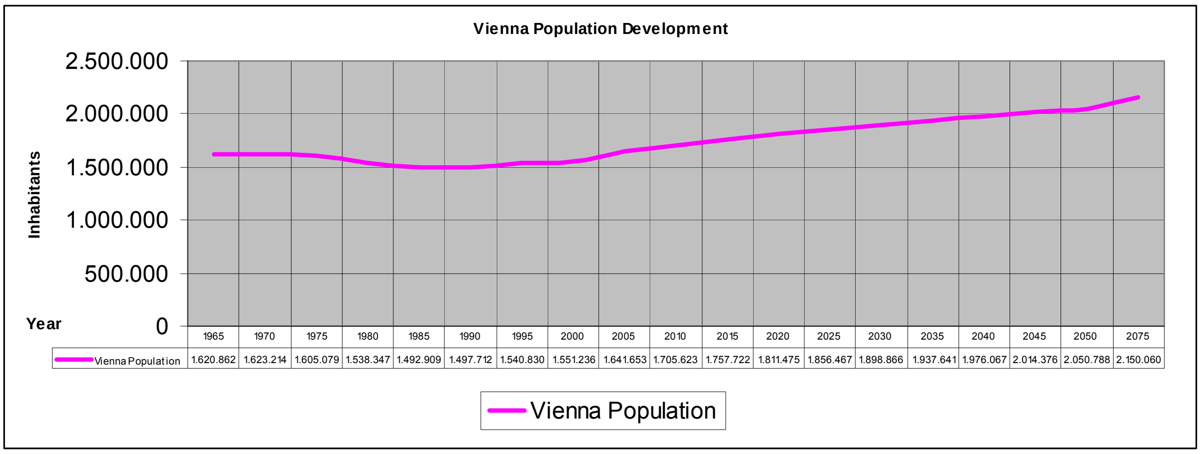
2.3.1 Data

The data are mainly obtained from the Austrian Statistical Office (ÖSTAT or Statistik Austria), from the relevant Vienna municipal departments (Magistratsabteilung abbreviated “MA”) in Vienna such as MA 48 (Waste Management), MA 22 (Environmental Protection), MA 28 (Road Construction and Maintenance), MA 29 (Bridges), federal Austrian authorities such as Federal Environmental Agency (Umweltbundesamt), and last but not least, from the Metapolis Study from Baccini et al. (1993) and Beschorner (1996).

2.3.2 Development of Vienna Population

In the first decade after the fall of the iron curtain 1991, there was widespread fear that Vienna would lose importance and other ascending metropolitan areas such as Prague or Budapest would overtake Vienna as the “Heart of Middle Europe”. The decline in the population during the post WW-II decades have contributed to this fear. However, to the astonishment of most, Vienna has grown and continues to grow since after reaching a low in 1987 with 1.484.885 people.

Since 1987, the city has grown steadily, reaching 1.551.236 in 2000, and accelerating to reach 1.680.170 in 2008 and 1.705.623 in 2010, representing a growth of 10% in the last decade. In addition, the prognosis for the next decades shows a continued – even accelerated – growth until 2075, with Vienna breaking the 2 Million mark around 2040/2045.



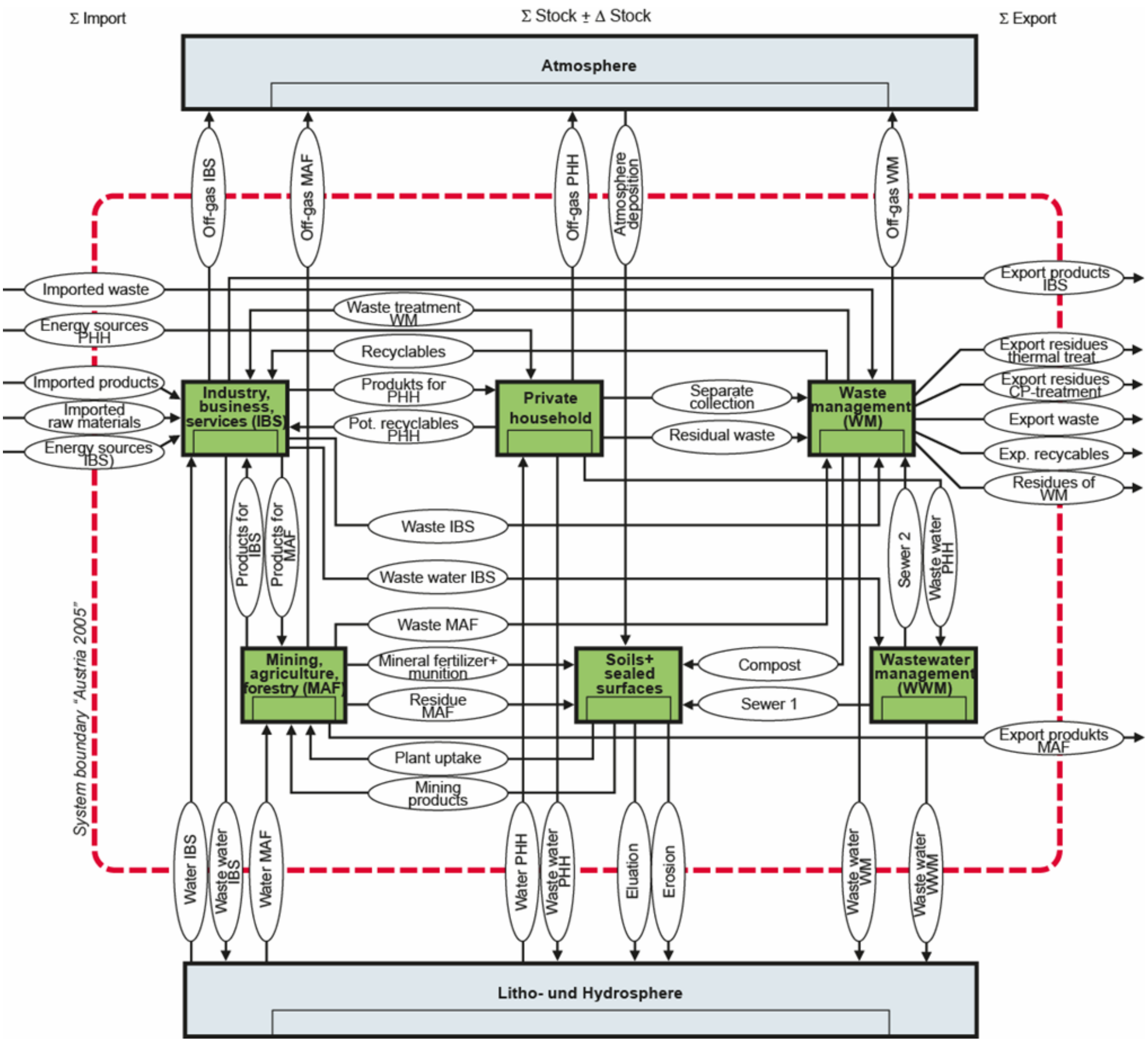
Graph 2-1 Vienna Population Development

In addition, the size of the Vienna Household has shrunk over the years, (Familien- und Haushaltsstatistik 2008: p. 31) hovering about 2 from 1998 onwards, reaching 1,99 persons per household in 2008.

Therefore, the average housing size per person in Vienna is 37,14 m^2.

2.4 Embedding of PHH in the Urban System

The Private Household (PHH) is defined as all private households within the boundaries of Vienna. The input of flows of goods discussed in this thesis are air, water, energy in the form of its carriers (mainly fossil), durable goods and consumable goods. The output of this process are off-gas, waste water and waste (construction/other waste, recycled waste and residual waste).



Graph 2-2 Embedding of PHH in Urban System
Source: TU-Vienna, IWA-Institute SCUDE Presentation Taiwan

3 The Four Activities of a PHH[1]

3.1 *Flows and Stocks of the Activities*

In the following chapter the aim is to define and describe the mass flows and stocks of the activities *To Nourish, To Clean, To Reside* and *To Transport and Communicate*. The reference year is 2008.

3.2 *To Nourish*

In the Activity *To Nourish*, all processes and goods to produce and prepare food for the PHH are included, as well as the release of wastes and the digestion and release to the environment as urine/feces. The breathing volume of an average human body was calculated by Baccini et al. (1993) as **6400 kg/c•a**[2], and the daily amount of consumed water was calculated as 3 liters per person per day, which can be translated in 1100 kg/c•a, of which 280 kg are directly consumed as drinking water (Baccini et al. 1993).

Regarding durable goods for this activity, the flow was calculated from the stock of 53,6 kg/a, of the main items mentioned in the consumer analysis of Statistik Austria, assuming 10 years life-time for each household equipment, i.e. **5,4 kg/c•a**, it is assumed that mainly white goods such as Stove, Refrigerator, Microwave are used as durable goods and disregard the even smaller equipments such as mixers, electric knives, coffee machines etc.

Year 2009/10	Activity	stock kg/pc.a	Avg Weight	% of PHH	Weight after %	pc/PHH
Household Equipment Nourish	**Total**	**53,59**				
Electric Stove	Nourish		50	90	44,95	22,59
Gas Stove	Nourish		50	11	5,65	2,84
Refrigerator	Nourish		50	99	49,74	24,99
Microwave	Nourish		7	90	6,3	3,17
Source: STATISTIK AUSTRIA, Konsumerhebungen 2009/10, 2004/05 und 1999/2000, Mikrozensus Sonderprogramme Juni 1974-1993 und September 1998. Erstellt am 12.04.2011. 1) Mikrozensus September 1998 vgl. Statistische Nachrichten, Heft 8/1999. - 2) Mikrozensus Juni and own calculations						

Table 3-1 Household Equipment To Nourish

As for the energy carrier use in the activity *To Nourish*, according to the study Gasverbrauch Austria (2006: p. 2), the average use of Gas for Cooking is about 11 m^3/c•a, therefore 11 m^3 * 0,714kg[3]/per m^3 **= 7,9 kg/c•a of Gas** for Cooking per person PHH.

[1] Baccini and Brunner 1991: 78ff
[2] 15 m^3 per day, including 0,33l of Water per day (Baccini et al. 1993)
[3] There are 1000 liters in one cubic meter. 22.4 liters of any gas is equal to 1 mole, according to molar volume. Main component of natural gas is methane (CH_4), with a molar

As for the consumption, the Consumer Study of Statistik Austria (2010) shows the following data, that the average per capita consumption for food and drinks according to this table is **838 kg/c•a.** It has to be noted, that consumption of food outside of the persons belonging to the private households outside of their homes in restaurants, company and school canteens is not considered here as they should be part of the industry/business services process.

Average monthy consumption of Food & Drinks	kg/per month	per year
Bread and cereal products	4,70	56
Meat, Sausages, Fish	4,80	58
Milk, Eggs	20,30	244
Butter, Oil	1,20	14
Fruits	5,50	66
Vegetables	5,40	65
Sweets, Coffee, Cocoa	2,20	26
Mineral Water, Sodas, Juices	13,60	163
Alcoholic Beverages	12,10	145
Source: STATISTIK AUSTRIA, Konsumerhebung 2009/10. Erstellt am: 12.04.2011	**69,80**	**838**

Table 3-2 Average monthly consumption of food and drinks

However, it has to be considered that not all food and drinks brought into the household is actually "consumed", there is a loss of food and drinks due to expiry of the products. A study from the Vienna BOKU University (Schneider 2010) differentiates between food and its origins in the the waste:

- Food preparation waste / not avoidable
- Food in original packing / avoidable
- Already opened food / avoidable
- Dish waste / mainly avoidable

Waste that goes into the residual waste was estimated at about **106 kg/c.a** (see table 4.2 Nourish in Residual Waste) - of which according to the study (Schneider 2010) 40 kg could be avoided – therefore the input is 838 kg of which 106 kg goes into the residual waste and an estimated the rest might go into the separate biological waste collection system, where the following items shall be collected: Waste of Fruits and vegetables, eggs, coffee, tee, trees, paper tissues, plant soil, flowers, leaves, which amounted to the total of 60kg (Fehringer and Fruewirth 2008), looking a the items list it can be estimated that only about 36% of this comes from

mass 16g per mol, therefore: 16g/mol * 1000L/ m^3 / 22.4 L/mol = 714g/ m^3 = 0.714kg/ m^3. One m^3 equals 0.714 kilograms in a cubic meter of natural gas.

the activity *To Nourish*, i.e. **22 kg**. The remaining Recyclable Waste consists of the flow of the durable goods (kitchen equipment) **of 5,4kg/c•a** PHH, assuming a 10 years life time for the stock and the rest would be food packaging.

As for the stocks, the average private household **stores about 21 kg/c of food and beverages (**assuming 3,33% of the Foods and Drinks purchased – for the calculation, unfortunately, the much higher rate of 10% and 84 kg/c has been used) and **54 kg/pc** of kitchen equipment.

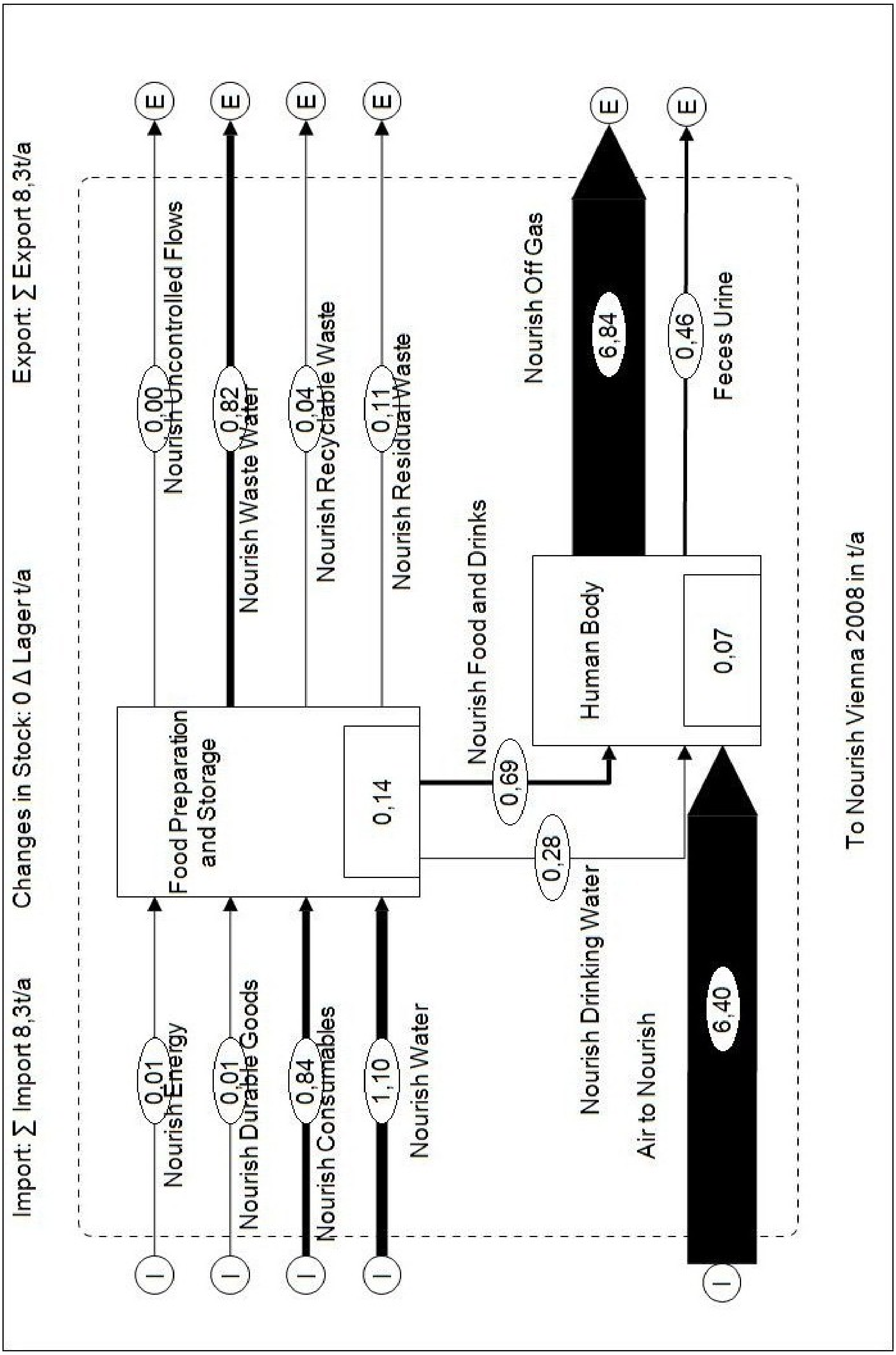
PROCESS FOOD PREPARATION AND STORAGE			
Input Goods	**Input Flow**	**Stock**	**Sources**
Air	6.400		Baccini et al. (1993)
Water	*1.100*		own calculations
Energy Carrier	*8*		own calculations
Consumable Goods			
Food & Drinks Flow	*838*		Konsumerhebung 2009/10
Food & Drinks Stock		28	own calculations
Durable Goods			
Kitchen Equipment Flow	*5*		own calculations
Kitchen Equipment Stock		54	Konsumerhebung 2009/10
Electric Stove		23	own calculations
Gas Stove		3	own calculations
Refrigerator		25	own calculations
Microwave		3	own calculations
Total Input	**8.351**		
Total Stock	-	82	
Total Output	**8.333**	Export to	
Air	6.400	Process Human Body	
Drinking Water	280	Process Human Body	Baccini et al. (1993)
Waste Water	815	Waste Water	own calculations
Food & Drinks	690	Process Human Body	Baccini et al. (1993)
Kitchen Food Waste	22	Recyclable Waste	own calculations
Equipment and Packaging	20	Recyclable Waste	own calculations
Residual Waste	106	Residual Waste	own calculations

Table 3-3 Food Preparation and Storage in kg/c.a 2008

For the human body stock the **average body weight** has increased from below 70 kg in 1990 (Beschorner 1996: p. 97) to **74 kg**. This trend can be explained on the one hand because of the decline in the ratio of children in the population, on the other hand because of an increasing trend in average weight according to the IMAS Report 5/2003, the average Austrian is 172 cm high and weighs 74 kg (Men: 178 cm and 81 kg, Women: 167 cm and 67 kg). (IMAS Report 5/2003, p. 1a)

PROCESS HUMAN BODY		
Input		**Source**
Air	*6.400*	Baccini et al (1993)
Drinking Water	*280*	VWWTP
Food & Drinks	*690*	own calculations
Total Input	**7.370**	
Output		Export to
Off Gas / Transpiration	*6.840*	Air
Feces/Urine	*456*	Water
Total Output	**7.296**	
Stock	74	Human Body

Table 3-4 Proces Human Body in kg/c.a 2008 Vienna PHH



Graph 3-1 MFA To Nourish t/a

3.3 *To Clean*

In a wider sense, *To Clean* comprises all processes to maintain human health and prevent it from pollution. The main good that dominates this activity is water, about 99% of the total flux, with an estimated 90kg needed per kg of feces/dirt.

Inputs for this activity are Energy to Heat Water, Consumable Goods and Durable Goods.

Consumables Flow of the Activity To Clean consists of washing powder, shampoos, soaps and other cleaning agents and has been estimated by Beschorner (1996: P: 32) at **20 kg/c•a** with a stock of 10%, i.e**. 2 kg/c.**

Durable Stock of the Activity *To Clean* consists of the equipment ("white goods") such as vacuum cleaner, dishwasher, iron, washing machine, clothing dryer and is estimated at **56,4 kg/c**, estimating a 10 years usage for the equipment we reach a flow of **5,6 kg/c•a**

Year 2009/10						
Stock of Household Equipment Clean	**Total**	**56,36**	**Avg Weight**	**% of PHH**	**Weight after %**	**56,36**
Dishwasher	Clean		50	74	36,85	18,52
Washing Machine	Clean		50	97	48,35	24,30
Clothes Dryer	Clean		50	34	16,95	8,52
Other (Vacuum Clean etc.)	Clean		10	100	10,00	5,03

Source: STATISTIK AUSTRIA, Konsumerhebungen 2009/10, 2004/05 und 1999/2000, Mikrozensus Sonderprogramme Juni 1974-1993 und September 1998. Erstellt am 12.04.2011. 1) Mikrozensus September 1998 vgl. Statistische Nachrichten, Heft 8/1999. - 2) Mikrozensus Juni and own calculations

Table 3-5 Household Equipment List Clean

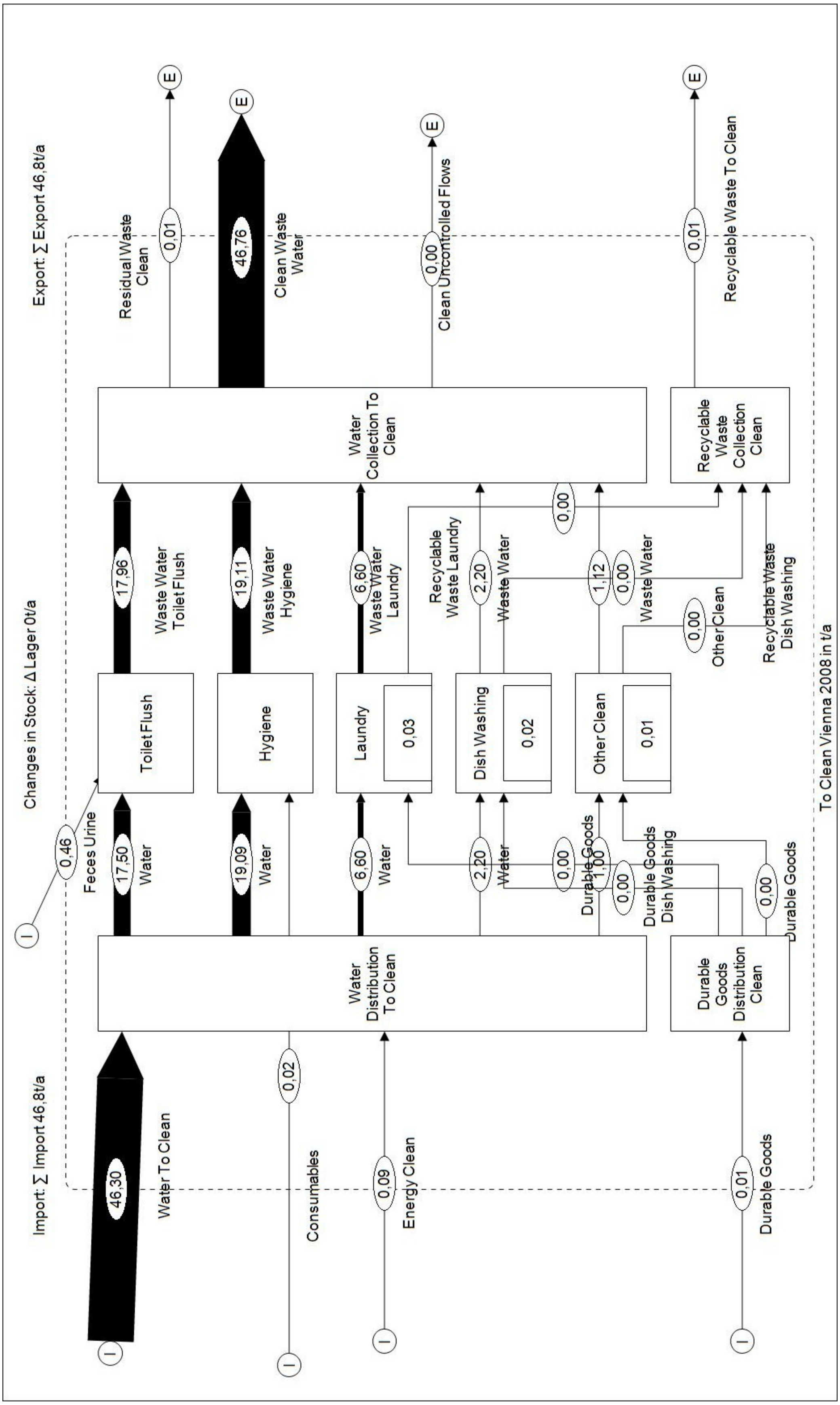
According to the study Gasverbrauch der Haushalte (2006: p. 2), the average use of Gas for Warm Water is about 127 m^3 per c•a, 127 m^3 * 0,714kg[4]/per m3 = **90,7 kg /c•a of Gas for Warm Water per person.**

In the following table the overview of this activity is presented.

[4] There are 1000 liters in one cubic meter. 22.4 liters of any gas is equal to 1 mole, according to molar volume. Main component of natural gas is methane or CH_4, with a molar mass 16g per mol, therefore: 16g/mol * 1000L/ m^3 / 22.4 L/mol = 714g/ m^3 = 0.714kg/ m^3. One m^3 equals 0.714 kilograms in a cubic meter of natural gas.

TO CLEAN OVERVIEW OF INPUT AND OUTPUT				
Input Goods	**Input Goods Flow**	**Stock**	**Remarks**	**Source**
WATER	46.300			Kläranlage Wien
Toilet Flush	*17.500*			Beschorner/Metapolis
Hygiene	*19.000*			Beschorner/Metapolis
Laundry	*6.600*			Beschorner/Metapolis
Dish Washer	*2.200*			Beschorner/Metapolis
Other Clean (Dish, Car etc)	*1.000*			estimation by author
ENERGY CARRIER	*91*			Gasverbrauch Austria 2006
CONSUMABLE GOODS	20	2	Shampoo, soap etc	Beschorner
Diapers	*13*			Residual Waste Analysis
DURABLE GOODS	6	56		Konsumerhebung 2009/10
Washing Machine		*24*	2	Konsumerhebung 2009/10
Clothes Dryer		9	1	Konsumerhebung 2009/10
Dish Waser		19	2	Konsumerhebung 2009/10
Other		5	1	Konsumerhebung 2009/10
INPUT from NOURISH	456			
Total Input			**Total Output**	
Total Input	46.872	58	*Waste Water*	46.756
			Residual Waste	13
			Heat Energy Loss	91

Table 3-6 Overview To Clean in kg/c.a 2008 Vienna PHH



Graph 3-2 MFA To Clean in t/a

3.4 *To Reside*

The activity *To Reside* can be separated into the three processes

1. Housing incl. Furniture, Clothing,
2. Heating
3. Plants

The main stock is the apportioned mass of the residential property, in addition the heating materials such as Heating Oil, Wood (and Wood Pellets), Coal and Gas. The heating via Distant Heating or Electric Energy and plants of the households has been neglected due to the fact that they represent a marginal value for the households.

3.4.1 Housing

According to the PILOT Study by Daxbeck et al. (1996: p.69), each PHH had a stock of about 130t *To Reside*.

In a newer study by Clement et al. (2011) the average material content of the Stock of Buildings in Vienna were estimated as follows:

63% Mineralic (Bricks, Sand, Gravel)
25% Concrete
2% Steel

If the average of 1996 was estimated at 130t/c, with an average household apartment size of 68 m^2, with the decline in numbers of person per PHH (2008: 1,99) and the additional residential building activity, this has risen to 73,9 m^2 by 2008 (ÖSTAT Wohnen 2008: p. 34), an increase of 8,7%. Therefore the increase of 8,7% is applied to the base number of 130 t/c, to reach **141,3 t/c** of stock per Viennese, this translates in an annual growth of 0,725%.

To check the plausibility of the numbers of PILOT study of Daxbeck et al. (1996), Bauwerk Österreich (2003) assumes as stock for the whole of Austria for private households the number of 650 Mio Mg (with a given bandwith of 489 Mio Mg to 865 Mio Mg) – if we break down this number of Austria for Vienna, we would reach approximately the same numbers for 2003: 650 Mio Mg stock / 8,118 Mio inhabitants * 1,6 Mio inhabitants Vienna = 128,11 Mg = **128 t/c** (if we take the Austrian numbers)

If we then try to break down the 141 tonnes into its main constituents, the mineralic material such as bricks, gravel and sand are dominant, then concrete and to a quite low extent steel. Wood does not play a role in this quantitative view. Therefore, the average households reside space is estimated to contain

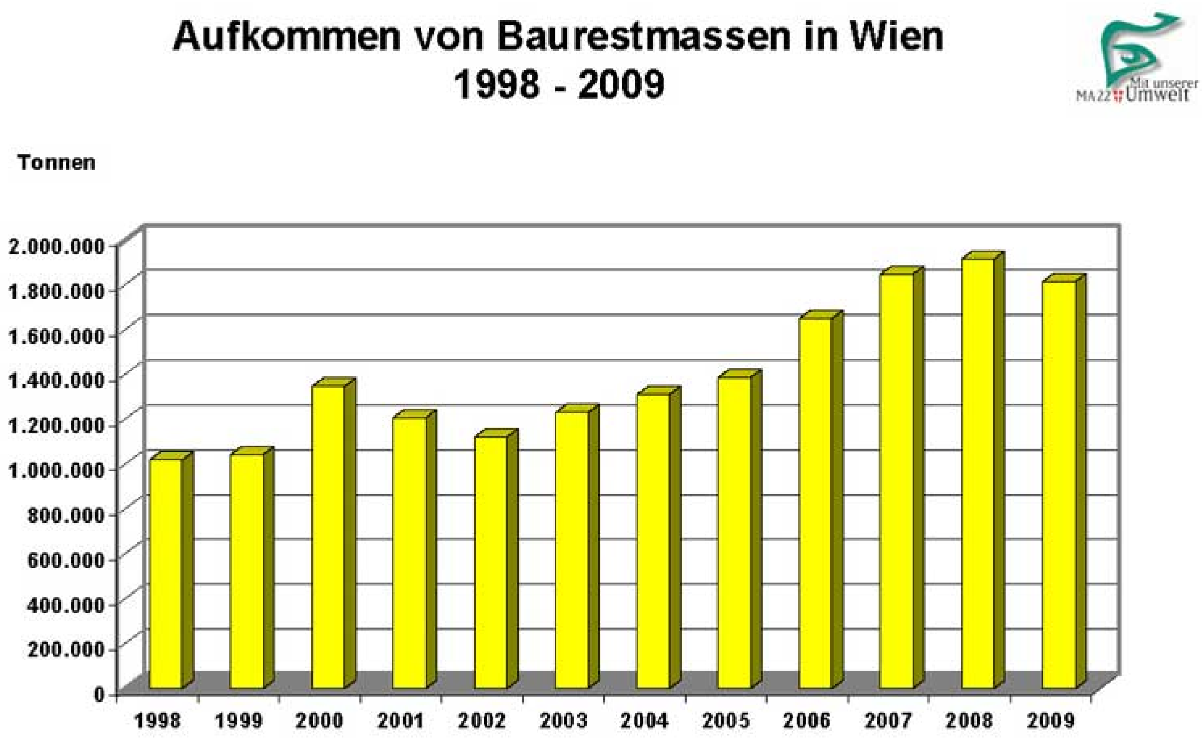
Average PHH/Vienna To Reside Space selected goods	Total / tons	%	Total / tons	Good
Bricks	141	63	89,02	Bricks
Concrete	141	25	35,33	Concrete
Steel	141	2	2,83	Steel

Table 3-7 Main Material in Vienna Buildings

The input flow into the process Housing is very difficult to estimate as there are no direct numbers that we can access. As a reference number, the number of yearly produced Vienna construction waste can be compared with the growing stock of residence space per capita.

Between 1996 and 2008, there was an annual growth of 0,725% of stock per capita, as the average available m^2 per capita grew from 68 m^2 to 73,9 m^2 in that period.

For 2008, the amount of 1.900.000 tons of construction waste was recorded for Vienna, which is attributed as the other residual waste with 82,75% for PHH and 17.25% for non PHH.



Graph 3-3 Construction Waste in Vienna

This gives the number of 1.572.250 for private households, which translates into **0,94 t/c.a PHH** of construction waste for the output flow for the process Housing.

Assuming 0,725% growth of stock p.a. for 2008, an input flow can be calculated for this year as follows: 0,936 tons * (100% + 0,75%) = **1,64 t/c.a for the PHH**.

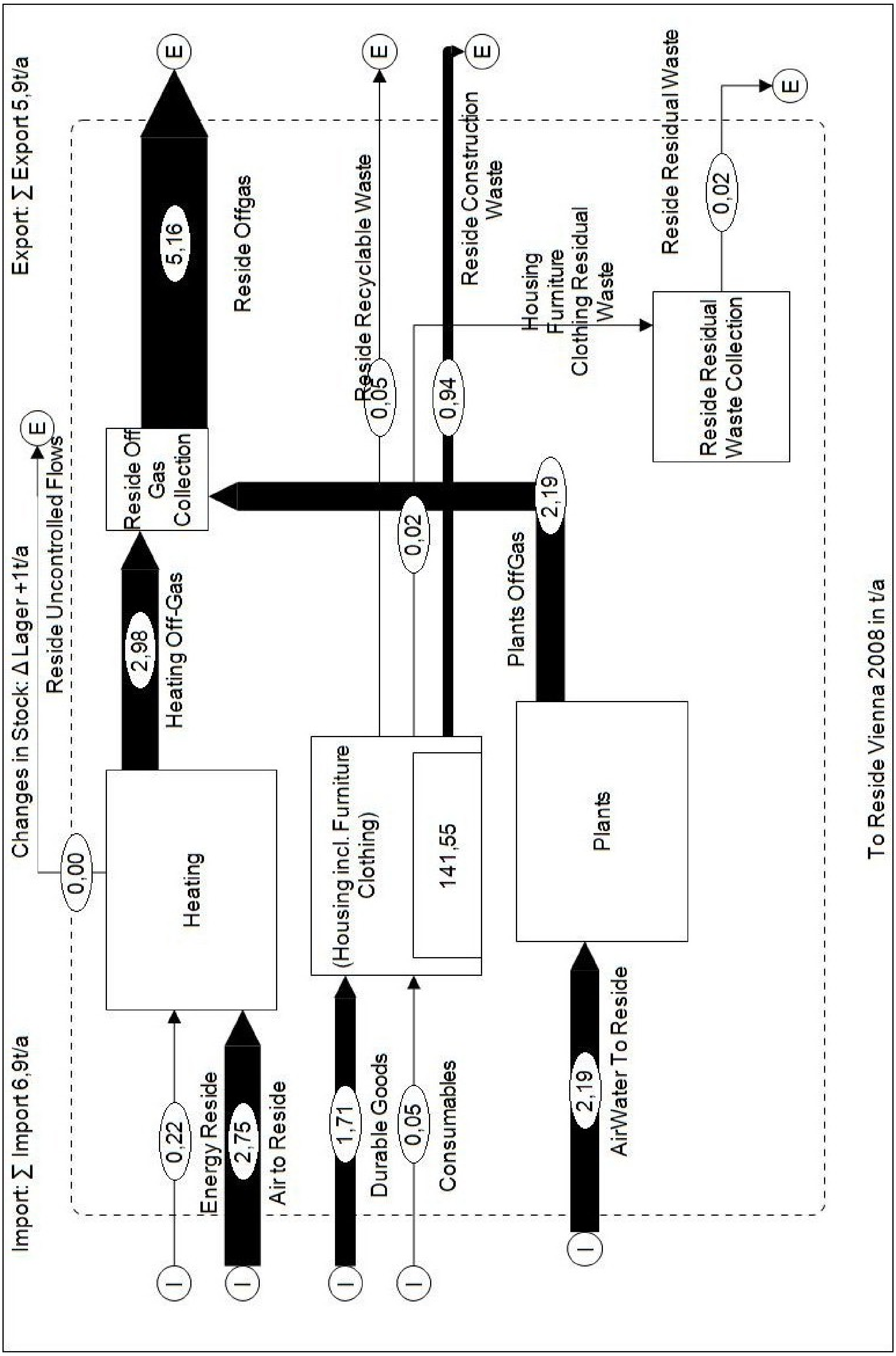
TO RESIDE OVERVIEW OF INPUT AND OUTPUT						
Input Goods	**Input Goods Flow**	**Stock**	**Air for Heating**	**Output Flow**	**Source**	**Export to**
Building Material	1.637	140.000		940	own calculations	Other Waste
Furniture	50	500		50	own calculations	Recyclable Waste
Clothing/Shoes	21	50		4	own calculations	Recyclable Waste
Summe Durables	**1.708**			17	own calculations	Residual Waste
Heating	**224**				own calculations	
Gas	*186*		2.486	2.672	own calculations	Air
Heating Oil	*15*		164	179	own calculations	Air
Wooden Pelletts	*21*		84	105	own calculations	Air
Coal	*2*		17	19	own calculations	Air
Nourish	*91*				own calculations	Total Air
Plants Air/Water	*2.190*			2.190	own calculations	Water/Offgas
Air for Heating	*2.751*	140.550			own calculations	
TOTAL	6.963			6.176	1 tons	added Stock

Table 3-8 Overview To Reside in kg/c.a 2008 Vienna PHH

Of this construction waste, only the tiny fraction of **80.8 tons** (4,25%) or **48 kg/ c•a per PHH** was deposited in Vienna, the rest was exported to other Austrian Bundesländer. For this paper, this export is calculated as it would stay in Vienna.

It has to be added, that this numbers was not cross-checked with the input numbers by the author: the other approach would be to calculate the input of construction material and the average resident time, which might lead to different numbers altogether.

Due to the fact that the construction companies who are located in Vienna do not keep separate numbers for the purchasing of construction material for the whole company and how much of this material is used for Vienna construction sites respectively outside of Vienna construction sites, this data is very difficult to come by and has therefore not been included in this thesis as a reference data.



Graph 3-4 MFA To Reside in t/c.a Vienna PHH 2008

3.4.1.1 Furniture and Clothing

Baccini et al. (1993: p.35) estimated the **Furniture at 500kg/c stock**, and **the clothing at 50kg/c stock**, with the yearly growth estimated at 1%, and accordingly the Output was estimated at 20kg/c•a for furniture.

In the master thesis of Weirich (2008: p.45), he estimated the mass in kg of the following furniture pieces of a PHH, if we then consider that one person in a PHH might have several chairs, 2 cupboards and add other not considered furniture such as book shelves etc., the 500 kg look plausible.

Furniture	kg
Chair	5,60
Table	45,00
Cupboard	228,00
Sofa	54,00
Kitchen	34,00
Mattress	16,00
	382,60

Table 3-9 Average Weight of Furniture in PHH

3.4.1.2 Consumables and others

As for the consumables and others for the process housing, a rough estimate number of 50 kg/c•a. perPHH was applied by the author.

3.4.2 Heating

The energy carrier used for heating in Vienna has changed over the recent century, the dominance of coal and heating oil has diminished dramatically, e.g. there has been a decrease in the use of heating oil in 2008 compared to 1990 by 17% and a remarkable 85% for coal (Österreich 2010: p. 78).

Heating in Vienna 2007/2008 according to type of Heating				
Type of Heating	# of PHH	%	kg needed for 37,136m2	TOTAL
Gas	456.642	54,94%	339,40	**186,48**
District Heating	*278.947*	*33,56%*		
Electricity	*51.506*	*6,20%*		
Heating Oil	25.929	3,12%	473,48	**14,77**
Wood, Wood Pelletts	15.259	1,84%	1.114,08	**20,45**
Solar	*1.649*	*0,20%*		-
Coal	1.172	0,14%	1.592,00	**2,24**
Total	831.103	100,00%	Total kg Heating	**223,95**
Source: STATISTIK AUSTRIA, Energiestatistik: MZ Energieeinsatz der Haushalte 2007/2008 & own calculations				

Table 3-10 Heating in Vienna 2007/2008 according to type of heating

To deviate shortly from the quantitative approach of this study and looking at the CO2 footprint of each heating method, there is a reason why gas is gaining attractiveness as is the energy carrier with the lowest emission per kWh. However, the dependency on imports from politically risky countries such as Russia or other gas exporters give room for concern.

CO2 Balance would be for the different energy carriers

Gas:	0,19 kg/kWh
Heating Oil:	0,28 kg/kWh
Coal:	0,32 kg/kWh
Winter Electricity:	0,35 kg/kWh
Summer Electricity:	0,18 kg/kWh

In this study only physical energy carriers are considered, therefore only gas, heating oil, wood and coal is taken into account. In a city like Vienna, the dominance of Gas and District Heating is eminent.

3.4.2.1 Gas

According to the study Gasverbrauch Austria (2006: p. 2), the average use of Gas for Heating is about 12,80 m^3 per m^2 p.a., 12,80 m^3 * 37,136 m^2 (average per capita housing size) = 475,34 m^3/c•a * 0,714kg[5]/per m^3 = 339,4 kg /c•a of Gas for Heating per person, then adjusted with the 54,94% of PHH the number of **186,5 kg/c•a** is calculated.

3.4.2.2 Heating Oil

For heating oil, numbers from Germany are used. According to the study of Techem AG[6], the usage of heating oil in Germany was in 2008/2009 at an average of 15 Liter per m^2, with 1 l Oil being 0,85kg. The calculation is therefore 15l * 0,85 * 37,136 m^2 = 473,48 kg then adjusted with the 3,12% of PHH we reach **14,8 kg/c•a**

[5] There are 1000 liters in one cubic meter. 22.4 liters of any gas is equal to 1 mole, according to molar volume. Main component of natural gas is methane or CH_4, with a molar mass 16g per mol, therefore: 16g/mol * 1000L/ m^3 / 22.4 L/mol = 714g/ m^3 = 0.714kg/ m^3. One m^3 equals 0.714 kilograms in a cubic meter of natural gas.

[6] Techem AG Study: Die Analyse basiert auf Daten von 331.209 Wohnungen in 63.314 Mehrfamilienhäusern in Deutschland. http://www.pressemitteilungen-online.de/index.php/durchschnittliche-warmwasser-und-heizkosten-in-deutschland/ (accessed 2011/05/30)

The quantity of air consumed per kg of Heating oil is calculated as 11,1 kg / kg Heating oil (Baccini et al. 1993) thus the amount of air necessary is **164 kg/c.a.**

3.4.2.3 Wooden Pellets

According to the simple calculation of wooden pellets from heating oil, the going rule[7] is to multiply the liters heating oil or the m^3 of gas with the factor 2: 15l (Heating Oil) * 2 * 37,14 m^2 = 1114,20 kg / c•a for Wooden Pellets, adjusted by the 1,84% of PHH we reach **20,5kg / c•a** The quantity of air consumed per kg of Wood is calculated as 4,1 kg / kg wood (Metapolis) thus the amount of air necessary is **84 kg/c.a.**

Wooden Pellets Ash residues could be used as compost, but in Vienna it is collected with the residual waste, however, this numbers are very low as 20,5 kg of pellets generate less than 0,2 kg of ash – therefore this numbers are not considered in the MFA.

3.4.2.4 Coal

According to a German article about taxation of coal as energy carrier, the going rule[8] for a 70 m^2 apartment is 3 tons of coal, therefore the necessary kg of coal for 37,14 m^2 is 1592 kg (= 3000 / 70 * 37,14), then adjusted with the 0,14% of PHH we **reach 2,2 kg/c•a.** The quantity of air consumed per kg of coal is calculated a is 4,1 kg/kg coal (Baccini et al. 1993) thus the amount of air necessary is **17,2 kg/c.a.** Coal Ash is collected as residual waste.

Coal ash is collected with the residual waste, however, the numbers are very low as 2,23 kg of coal generate less than 0,1 kg of ash – therefore this numbers are not considered in the MFA.

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[7] Wieviel Holz muss ich fuer die Beheizung kaufen?
http://www.energieberatung-hessefort.de/brennholz.html#2.12
(accessed 2011/05/28)

[8] Kohlesteuer belastet Verbraucher
http://www.morgenpost.de/printarchiv/wirtschaft/article262819/Kohlesteuer_belastet_Verbraucher.html
(accessed 2011/05/22)

3.5 To Transport and Communicate

This activity consists of the main processes transport of people and goods, transfer of information and packaging. The process of packaging has been included due to its increased important, as we are more and more dependent of the transfer of goods, and in order to make the goods transportable, they have to be packaged.

To illustrate the importance of this issue, e.g. in 2008, Viennese collected 85,5 kg/c•a of Packaging Material such as board, paper, glass and cans. It is assumed that in addition, at least 10% is thrown away into the residual waste (see table 4.2), therefore the total per head consumption of packaging is estimated at 94,1 kg/c•a for the PHH, with 85,5 kg/c•a going into recycling and 8,6 kg/c•a going into the residual waste.

The stock consists of private cars, bicycles, information technology tools such as computer, television, Hi-Fi Stereos, telephones but also the apportioned part of the infrastructure of roads and public transport and telephone infrastructure and lines, with the latter two being neglected here in this paper due to the fact that their mass is in no relevance to the stock of roads and public transport and data will be difficult to collect.

With regards to paper and CDs and the like, this has been included in the other Small Equipment items.

3.5.1 To Communicate Household Equipment

The Household Equipment sector has gone through major changes in the last decade, with the PC and the smartphones now taking more and more the centre stage of the list.

The Stock can be estimated at **23,2 kg/c for the PHH,** and given an average 3 year live span for these kind of equipments, a flow of about **7,7 kg/c.a** can be calculated.

Comparing this number with the calculated flow, VWMA MA 48 only gives statistics for monitors with 2.385 tons collected, which is about 1,42 kg/c.a for the PHH. Given that not all monitors and PCs are thrown away, but maybe exported for use in other less developed countries or as reserve equipment in the second country residence the calculated number seems realistic.

Regarding the consumables for *To Communicate* with items like paper, empty CD/DVDs or Video Tapes, a general estimate of **5 kg/c.a per PHH** is applied.

Year 2009/10	Activity	stock kg/pc.a	Avg Weight	% of PHH	Weight after %	pc/PHH
Household Equipment Communicate	**Total**	**23,16**				
Fixed Phone	Communicate		5	59,00	2,95	1,48
Mobile Phone	Communicate		1	91,00	0,91	0,46
PC	Communicate		10	71,00	7,10	3,57
TV	Communicate		20	97,00	19,40	9,75
VCR	Communicate		5	77,00	3,85	1,93
Video Camera	Communicate		2	24,00	0,48	0,24
Hifi Stereo	Communicate		10	64,00	6,40	3,22
Other Small Equipment	Communicate		5	100,00	5,00	2,51
TOTAL pc/PHH Stock						**23,16**

Source: STATISTIK AUSTRIA, Konsumerhebungen 2009/10, 2004/05 und 1999/2000, Mikrozensus Sonderprogramme Juni 1974-1993 und September 1998. Erstellt am 12.04.2011. 1) Mikrozensus September 1998 vgl. Statistische Nachrichten, Heft 8/1999. - 2) Mikrozensus

Table 3-11 Household Equipment To Communicate

3.5.2 Road Infrastructure

According to the Vienna Master Plan for Traffic (Master Plan Verkehr Wien 2003), the Commercial Traffic is responsible for 10% of Vienna total traffic, but contributes more than 20 to 25 % of CO2-Emissions and 70 % of Nox emissions. The Commercial traffic also is a major factor in terms of noise pollution and accelerates the wear and tear of the roads.

Following the calculation method laid out in the PILOT project, (1993: p.70) and the Information on the Internet of the Vienna Road Infrastructure, Vienna Roads have a total length of 2.800 Km, thereof:

51 km highway

216 km main roads

2.745 km secondary roads

1.100 km bicycle roads

With a total area of 40 k m^2, the one major increase since 1993 has been the increase in 13km of additional highways, so we can add (13km * 30m width *1,5tons/ m^2) = 0,5 million tons to the number of 1993, which was 50,9 Million tons, thus reaching 51,4 million tons of roads in Vienna, which means a stock of about

30,6 tons in total and per person we deduct 10% for the commercial traffic we reach **27,5 t/c for the PHH stock in roads**.

According to the MA 28 (Road Construction and Maintenance), the average life-time for a road with asphalt cover is 20 years, and for concrete cover is 30 years, including some renovation work every 10 years.[9]

For the calculation of the flow, an average lifetime of 25 years is applied to the stock with no growth, and an average recycling rate of 84 % is considered.

For Bridges, the numbers from 1993 can still be used as there were not many new constructions since then, with a stock of 5 million tons, which can be calculated as 3 tons / pc PHH, and if 10% is deducted for commercial traffic, the number of **2,7 t/c for the PHH in bridges** is reached. As for the calculation of the flow, the lifetime of bridges is estimated as 100 years, according to the MA 29 (Bridge Construction).

Infrastructure	**kg p.c/PHH**
Roads	27.540,00
Bridges	2.700,00
Subway	3.000,00
TOTAL	**33.240,00**
Source: PILOT, Master Plan Verkehr Wien and own calculations	

Table 3-12 Transport Infrastructure

3.5.3 Public Transport

3.5.3.1 Infrastructure

For the Subway Infrastructure, 5,7 million tons were given as a number in 1993 for 43 kms – as the total km of Subway has increased in Vienna until 2008 by 32 km to reach a total of 75 km which is an increase of about 76%, the Subway Infrastructure can be estimated 2008 at 10 tons of mainly concrete, which can be calculated as 3 tons / pc PHH stock, under the assumption that all Subway traffic belongs to PHH. (see table Transport Infrastructure). As for the lifetime, Subway tracks have a

[9] Information from MA 28 Mr.Zant via official letter GA-26282/11 on October 5, 2011

lifetime between 10 and 35 years according to the Vienna Municipal Transport Authority[10] (Wiener Linien), depending on the utilization and curve radius. For the calculation of the flow based on the stock, a lifetime of 30 years have been applied.

3.5.3.2 Public Transport Vehicles

According to the information of Mr. Lang from the Wiener Linien, there are 135 Subway Trains running in Vienna, as well as 513 Trams and 500 Busses. Thus the stock of Public **Transport Vehicles PHH can be estimated at 21,4 kg/c.**

Public Transport	# of Units	kg / Unit	Total	kg p.c/PHH
Subway	135	40.000	5.400.000	3,21
Tramway	513	43.000	22.059.000	13,13
Bus	500	17.000	8.500.000	5,06
TOTAL				21,40
Source: Wiener Linien, Fanpage Wiener Linien and own calculations				

Table 3-13 Public Transport Vehicles[11]

The lifetime of the Public Transport Vehicles was given by the Wiener Linien as 16 years for busses, 30 years for subway and 40 years for tramways.

As the consumption of LPG Gas compared to the individual traffic broken down per head is negligible, therefore this flow is not considered MFA.

[10] E-mail information from Wiener Linien, Ms. Mueller on Sept. 23, 2011

[11] Information from Mr. Lang of Wiener Linien and Fanpage der Wiener Linien / Fahrzeuge Fanpage der Wiener Linien: http://www.fpdwl.at/fahrzeuge/index.php (accessed 2011/05/29)

Types used for averages: Tramway: Siemens B1 , Bus: ÖAF GräfandStift Austria Type NG 235 M18 and U-Bahn: Bombardier Typ 1

3.5.4 Individual Transport

3.5.4.1 Stock of Individual Transport

Statistik Austria shows for Vienna in 2008 a stock of 657.426 vehicles and 73.336 Motorbikes..

Vehicles in Vienna since 2002							
Jahr	**Vehicles registered on January 1 of each year**						
	Total						
		Passenger Vehicles	**Busses**	**Transport Vehicles**	**Farming Vehicles**	**Other Vehicles**	**Motorbikes**
2002	**782.510**	646.283	3.725	58.968	3.182	5.001	65.351
2003	**784.865**	647.382	3.641	58.132	3.212	4.993	67.505
2004	**790.963**	652.418	3.602	58.396	3.282	4.907	68.358
2005	**794.109**	655.172	3.678	58.322	3.348	4.789	68.800
2006	**795.480**	655.806	3.535	58.506	3.411	4.794	69.428
2007	**799.748**	658.081	3.546	58.742	3.417	4.766	71.196
2008	***802.209***	***657.426***	***3.604***	***59.619***	***3.487***	***4.737***	***73.336***
2009	**805.539**	657.192	3.607	60.628	3.546	4.747	75.819
2010	**814.624**	663.926	3.726	60.796	3.573	4.645	77.958
Source: Statistik Austria – Kfz-Bestand.							
From: STATISTISCHES JAHRBUCH DER STADT WIEN **-** 2010 p.39							

Table 3-14 Number of Vehicles in Vienna 2002-2010

If we take the average car which is a VW Golf V with a average weight of about 1,3 tons, then the stock PHH c•a is about 510 kg.[12]

As for motorcycles, there were 73.336 units in Vienna, which gives us 0,044 motorbikes per capita, if we take the average motorbike at 200 kg[13] we reach about 9 kg PHH c•a Then we assume that every person in Vienna has a bicycle with about 10 kg, as some people have several bicycles and some none, I assume 1 bicycle

[12] Golf V varies in weight between 1,2 to 1,4 tons depending on model
[13] Motorbike as somewhere in the middle beween a Vespa 125 with 110 kg and a Harley Davidson with 350 kg.

per head in Vienna. Therefore total stock in individual vehicles per head is about **530 kg/c for the PHH.**

Individual Transport	Number	Reference Population	%	kg	kg/p.c.	Year of Use	Yearly Flow
Cars (Vienna)	657.426	1.680.170	39,13%	1.300	508,67	10	50,87
Motorcycles (Vienna)	73.336	1.680.170	4,36%	200	8,73	10	0,87
Bicycles (Vienna)			100,00%	10	10,00	10	1,00
				TOTAL	527,40		52,74
Source: STATISTISCHES JAHRBUCH DER STADT WIEN - 2010 and own estimates							

Table 3-15 Stock of Individual Transport Vehicles

3.5.4.2 Flows of Individual Transport

According to the Evaluation in 2008 of the Traffic Management Master Plan of Vienna from 2003 (Master Plan Verkehr Wien 2003, Evaluation 2003)[14], Vienna succeeded in reducing the daily individual vehicle km driven per head per day in Vienna from 6,3 km in 2003 to 6,1 km in 2008, this gives us per head per year 6,1 km x 365 days x 0,075 l/km[15] = 167l x 0,8 = **133,6 kg/c.a PHH of Fuel.** [16]

As for the amount of air needed, only individual cars are considered, with the amount for the public transport being negligibly low per capita, with diesel motors consuming 22 kg of Air per kg of fuel and petrol motors consuming 14,5 kg or air per kg of petrol (Baccini et al. 1993), and assuming that in Vienna there is a equal split between diesel and petrol engines, the average of **18,3 kg/c•a** of air per kg of fuel is consumed, which is about 2440 **kg/c.a PHH of Air for individual transport.**

Assuming a 10 years usage for each **vehicle type**, a flow of **53 kg/c•a for the PHH** is calculated, however, if this calculated number is compared to the actual number of 2008 of 0,57kg/c•a PHH for car wrecks, then it can be assumed that the lifetime maybe longer but more importantly most of the cars are exported out of Vienna before they are wrecked.

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14 http://www.wien.gv.at/stadtentwicklung/strategien/mpv/evaluierung/evaluierungsergebnisse.html (accessed 2011/06/01)

15 acccording to Energieeinsatz der Haushalte (Mikrozensus 2007/2008) - Fahrleistungen und Treibstoffeinsatz privater Pkw, Ergebnisse fuer Wien, Q: STATISTIK AUSTRIA, Energiestatistik: Mikrozensus Energieeinsatz der Haushalte 2007/2008. Erstellt am 30.12.2008 – the average consumption is 7,5l per 100 km = 0,075 liter per km.

16 Beschorner 1996 gives the number of 318,4 kg – It can only be assumed that the average consumption of a car in 1993 was higher and that he included km driven outside of the city boundary.

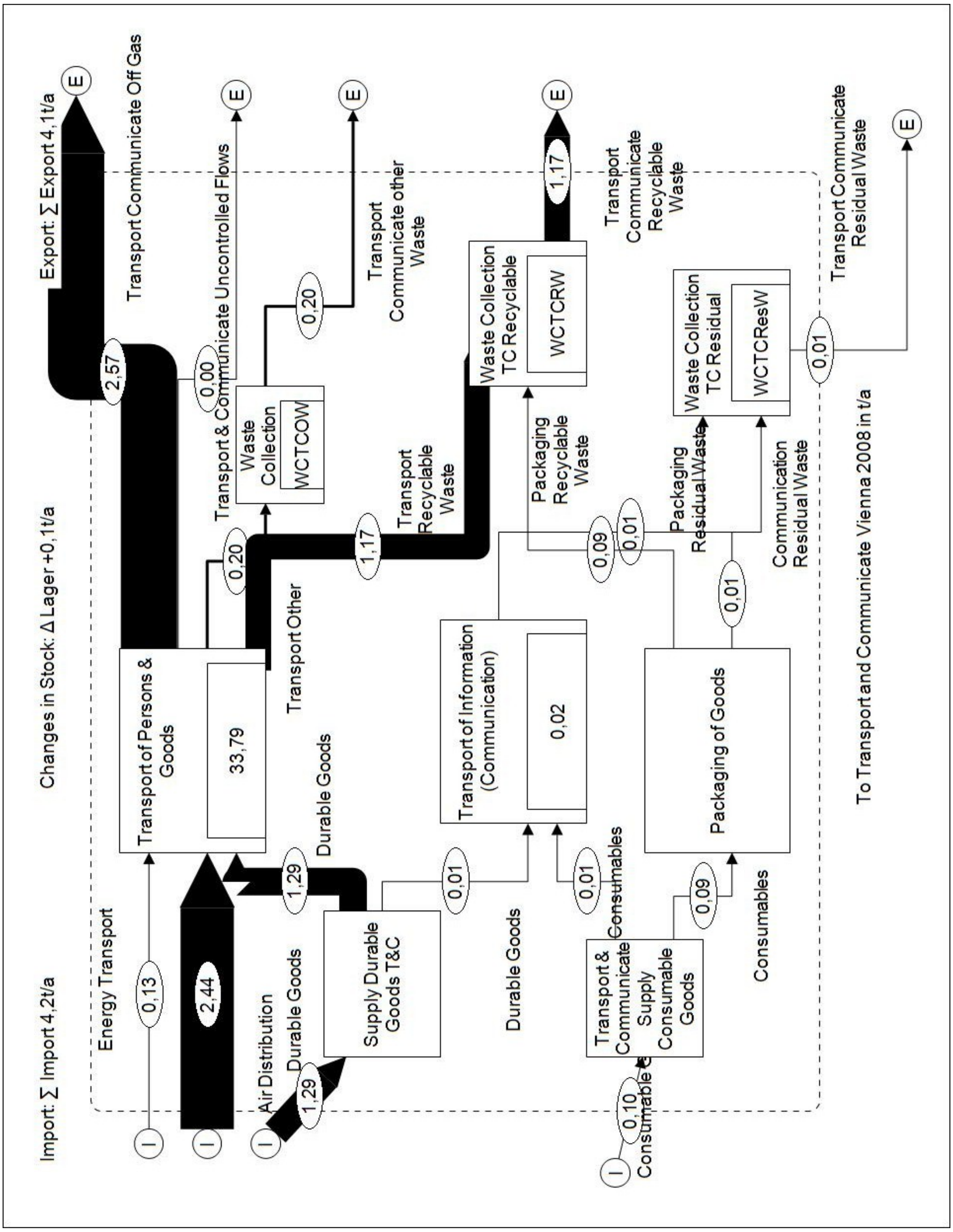
It is very eye-catching that only about 1 in 100 cars of Vienna is collected by the Vienna waste management. The system of car wreck management is a problem, as there is the assumption that many are exported illegally to Easter European countries as end of life vehicles.[17]

The following table shows the calculated flow for this activity

TO TRANSPORT AND COMMUNICATE OVERVIEW OF INPUT AND OUTPUT						
Items	**Input Flow kgs**	**Stock in kg**	**Output Flow kgs**	**Export to**	**Remarks**	**Source**
Roads	1.102	27.540	1.102	Other Waste (16%) /Recycling (84%)	25 years lifespan	MA 28
Bridges	27	2.700	27	Other Waste (16%) /Recycling (84%)	100 years lifespan	MA 29
Subway	100	3.000	100	Other Waste (16%) /Recycling (84%)	30 years lifespan	Wiener Linien
Public Transport Vehicles	2	21	2	Recycling	10 years lifespan	Wiener Linien / own calculation
Individual Transport Vehicles	53	530	53	Recycling	10 years lifespan	own calculation
Communicate Equipment (Durable)	8	23	8	Recycling	3 years lifespan	own calculation
Subtotal Durables	1.291	33.815	1.291			
Air for Individual Transport	2.440	-	2.440	Air		own calculations
Energy Carrier for Individual Transport	134	-	134	Air		own calculations
Subtotal Air/Energy	2.574	-	2.574			
Cons total incl Packaging	99	-	86	Recycling		own calculations
Cons without Paper Tape CD	94		9	Residual Waste		own calculations
Transport Energy Carrier	53	-	53	OffGas		own calculations
Information Carriers	13	-	13	Residual Waste		own calculations
Packaging other	86	-	86	Recycling		own calculations
Subtotal Consumables	345		245			
TOTAL	4.209,56		4.110,51	99,05	added stock p.a.	

Table 3-16 Overview To Transport and Communicate in kg/c.a Vienna 2008

17 http://www.wienerzeitung.at/nachrichten/panorama/chronik/371954_Wohin-verschwinden-Autowracks.html (accessed 2011/10/23)



Graph 3-5 MFA To Tranport and Communicate in t/a

4 Results and Discussions

In this chapter I endeavour to match quantitatively the contributions of the different activities to the relevant sinks. Generally one could say that the contribution of the activities to the sinks is very difficult to match, as the datasets for both sides come from not related and non-interlinked sources, which act independently from each other and with different focuses and interests.

The inputs can only be generated from consumer statistics, then we have the Black Box Process of the PHH and then we can measure the outputs. How much stock is accumulated, how much is exported outside of Vienna boundaries is often left to general assumptions.

On the waste side, the composition of the waste in Vienna is well documented with the exception of construction waste and end of life vehicles. There are also available input numbers for each of the items that are consumed, however, there is no overall system that can show the input and output flows and stocks of a Vienna household that this paper can be based on, but only the aim to match major flows and provide some insights on how which activities contribute to the sinks.

4.1 Contribution of the Activities to the Sinks

In order to finally calculate and analyse the contribution of the four activities to the sinks, it is necessary to clarify the following.

The stocks and flows are calculated, weighed and estimated by different sources and then combined and adjusted to generate a logical picture.

From the difference in the number of input flows, stock on the one hand and collected waste on the other hand it can be assumed that

a) the stock in Vienna is growing
b) there is a significant number of uncontrolled flows
c) there is significant export going on.

As how to treat this dilemma between the much too low numbers in the waste collection side, the following logic was applied.

If the export serves the purpose of recycling, such as cars, then only the actual numbers of the waste collection in Vienna are considered for its impact on the Vienna sinks.

If the export is for the purpose of waste deposit such as in the case of construction waste, then the whole yearly construction waste generated in Vienna is considered for its impact on the Vienna sinks.

The Vienna Waste Management Authority (VWMA, German: MA 48) publishes her the yearly performance report (MA 48 Leistungsbericht 2008: p. 35) a detailed list of all waste categories that are collected and treated by them. As the categories speak for themselves, they can be translated directly into an activity, such as cooking oil for *To Nourish* or textiles for *To Reside*. If there are two possible usages such as in the case of wood (*To Reside* or *To Transport and Communicate*), the more common usage is chosen.

As for the Residual Waste, this needs further investigation.

4.1.1 Residual Waste Analysis

Residual Waste, that is not collected separately and mostly incinerated, is the bulk of waste of a Vienna PHH. It can contain also recyclable material; however it is deposited in the residual waste, and therefore lost for the recyclable waste treatment. The latest analysis of Residual Waste, which is not collected separately, dates back from 2003/2004, and, as a comparison, the numbers from 1997/98.

Vienna Residual Waste Analysis	1997/98			2003/2004		
	%	tons	kg/pc.a	%	tons	kg/pc.a
Diapers	3,42%	15.625	9,72	4,29%	21.635	13,46
Biomaterial	37,56%	171.712	106,86	35,87%	181.004	112,65
Textiles	3,01%	13.769	8,57	3,19%	16.096	10,02
Wood - Leather - Rubber	4,27%	19.536	12,16	1,95%	9.854	6,13
Shoes	0,00%	-	-	0,67%	3.392	2,11
Paper and Board	15,86%	72.483	45,11	16,32%	82.369	51,26
Mineralic Substances	12,12%	55.416	34,49	12,69%	64.051	39,86
Glass	4,86%	22.220	13,83	5,68%	28.680	17,85
Compounds	4,17%	19.057	11,86	5,53%	27.927	17,38
Plastic - Bodies	3,02%	13.824	8,60	4,01%	20.254	12,60
Plastic - Foils	3,74%	17.118	10,65	3,32%	16.778	10,44
Metals	2,99%	13.658	8,50	3,17%	16.020	9,97
other Plastics	1,76%	8.035	5,00	1,55%	7.806	4,86
Hazardous Waste	1,16%	5.322	3,31	0,75%	3.804	2,37
Electronic Waste	0,86%	3.914	2,44	0,75%	3.766	2,34
Other	1,19%	5.420	3,37	0,25%	1.242	0,77
Total	**100%**	**457.109**	**284**	**100%**	**504.678**	**314**
Vienna Population			1.606.843			1.627.173
Source: WAWK Ist 2008 p. 94 (Vienna Waste Management Concept)						

Table 4-1 Vienna Residual Waste Analysis

Based on this analysis of 2003/2004, the same percentage to the residual waste of 2008 was applied and then attributed them to the four activities, resulting in the kg/c•a numbers for the different items in the residual waste and then grouped to the respective activity:

2008			Vienna Residual Waste Analysis	Activity	Total
tons	%	kg/pc.a	Items in Residual Waste		
0,04	4,29%	12,69	Diapers	**Clean Total**	**13**
0,36	35,87%	106,16	Biomaterial	**Nourish Total**	**106**
0,03	3,19%	9,44	Textiles	Reside	
0,02	1,95%	5,78	Wood - Leather - Rubber	Reside	
0,01	0,67%	1,99	Shoes	**Reside Total**	**17**
0,16	16,32%	48,31	Paper and Board	Transport / Communicate	
0,13	12,69%	37,57	Mineralic Substances	Transport / Communicate	
0,06	5,68%	16,82	Glass	Transport / Communicate	
0,06	5,53%	16,38	Compounds	Transport / Communicate	
0,04	4,01%	11,88	Plastic - Bodies	Transport / Communicate	
0,03	3,32%	9,84	Plastic - Foils	Transport / Communicate	
0,03	3,17%	9,40	Metals	Transport / Communicate	
0,02	1,55%	4,58	other Plastics	Transport / Communicate	
0,01	0,75%	2,23	Hazardous Waste	Transport / Communicate	
0,01	0,75%	2,21	Electronic Waste	Transport / Communicate	
0,00	0,25%	0,73	Other	**Transport / Comm. Total**	**160**
497.040	**100%**	**296**		kg/pc.a Total	**296**
		1.680.170			
own calculations based on WAWK Ist 2008					

Table 4-2 Residual Waste Vienna according to Activities

Of total residual waste of 600.686 tons, the amount of 497.040 (82,75%) tons can be attributed to PHH, the remaining 103.646 tons (17,25%) come from non PHH-waste, including household-like waste from industry, road waste collection and hospitals (MA 48 Leistungsbericht 2008: p.35)

This means, that for the separately collected or itemized waste, we could use this percentage for attributing this waste to PHH (82,75%) or non PHH (17,25%).

In the Report of the Vienna Municipal Waste Management Department we find the following numbers as a Input/Output Balance.

4.1.2 Contribution of Activities to the Imports and Exports

In the following an overview of the contribution of the various activities to the different import and export categories are shown.

The following table shows a summary of the imports per activity.

Overview of Imports of the Activites in kg/c.a																		
Import/Activity	Air			Energy Carriers			Durable Goods			Consumable Goods			Water			Total kg		
Activity	%	kg/c.a	%	%	kg/c.a	%		kg/c.a	%	%	kg/c.a	%	%	kg/c.a	%	%	kg/c.a	%
To Nourish	*77%*	6.400	55%	*0,1%*	8	2%	*0,1%*	5	0,2%	*10%*	838	83%	*13%*	1.100	2%	*100%*	*8.351*	13%
To Clean	*0%*	-	0%	*0,2%*	91	20%	*0,0%*	6	0,2%	*0,04%*	20	2%	*99,7%*	46.300	93%	*100%*	*46.417*	71%
To Reside	*40%*	2.751	24%	*3%*	224	49%	*25%*	1.708	57%	*1%*	50	5%	*32%*	2.190	4%	*100%*	*6.923*	11%
To Transport	*62%*	2.440	21%	*3%*	134	29%	*33%*	1.291	43%	*2%*	99	10%	*0%*	-	0%	*100%*	*3.964*	6%
Total kg of Imports		**11.591**	**100%**		**457**	**100%**		**3.005**	**100%**		**1.007**	**100%**		**49.590**	**100%**		**65.649**	
% or all Imports		18%			1%			5%			2%			76%			100%	100%

Table 4-3 Overview of the Imports of the Activities in kg/c.a Vienna 2008 PHH

The main import is water (76%) and air (18%), and each activity (except *To Reside,* which makes evenly use of all import categories) is dominated by different imports, *To Clean* by water (93%), *To Nourish* by air (77%) and *To Transport* by Air (62%)

The imports go through various processes in the different activities and are then exported. Import of air is mostly transferred into off-gas, but if the numbers are compared they are not equal, 11,592 kg/c.a for imports and 12,835 for kg/c.a for exports, air has been added with water vapour and particles from fossil combustion.

In the case of water, there is higher import with 49,590 kg/c.a but only 48,027 kg/c.a of waste water exports, this can be mainly explained by the evaporation into offgas.

For energy carriers, they will be exported to offgas and to residual waste.

For durable and consumable goods, the picture is complicated and these two categories extremely broad on the level of goods, that is why for a more insightful analysis, further studies will need to be undertaken at the level of specific, further itemized goods and substances.

For both categories of goods, after export, they will be treated in the waste management system.

Overview of Exports of the Activities																		
Export	**Waste Water**			**Off Gas**			**Residual Waste**			**Recyclable Waste**			**Other Waste**			**Total kg**		
Activity	**%**	**kg/c.a**	**%**		**kg/c.a**	**%**		**kg/c.a**	**%**		**kg/c.a**	**%**		**kg/c.a**	**%**		**kg/c.a**	**%**
To Nourish	*15%*	1.271	3%	*83%*	6.840	55%	*1%*	106	37%	*1%*	42	4%	*0%*	-	0%	*100%*	8.259	13%
To Clean	*100%*	46.756	97%	*0%*	-	0%	*0%*	-	0%	*0%*	6	0%	*0%*	-	0%	*100%*	46.762	74%
To Reside	*0%*		0%	*75%*	2.975	24%	*0%*	17	6%	*1%*	54	5%	*24%*	936	84%	*100%*	3.982	6%
To Transport	*0%*	-	0%	*65%*	2.570	21%	*4%*	163	57%	*27%*	1.071	91%	*4%*	177	16%	*100%*	3.981	6%
Total kg to Exports		**48.027**	**100%**		**12.385**	**100%**		**286**	**100%**		**1.172**	**100%**		**1.113**	**100%**		**62.983**	**100%**
		76%			20%			0%			2%			2%			100%	

Table 4-4 Overview of Exports of the Activities in kg/c.a Vienna 2008 PHH

Except for exports to off-gas which numbers can be used directly, all other export categories such as Waste Water, Recyclable Waste, Residual Waste and Other Waste are further processed or exported in the waste management system and need further adjustment in their relevance in the contribution to the sinks.

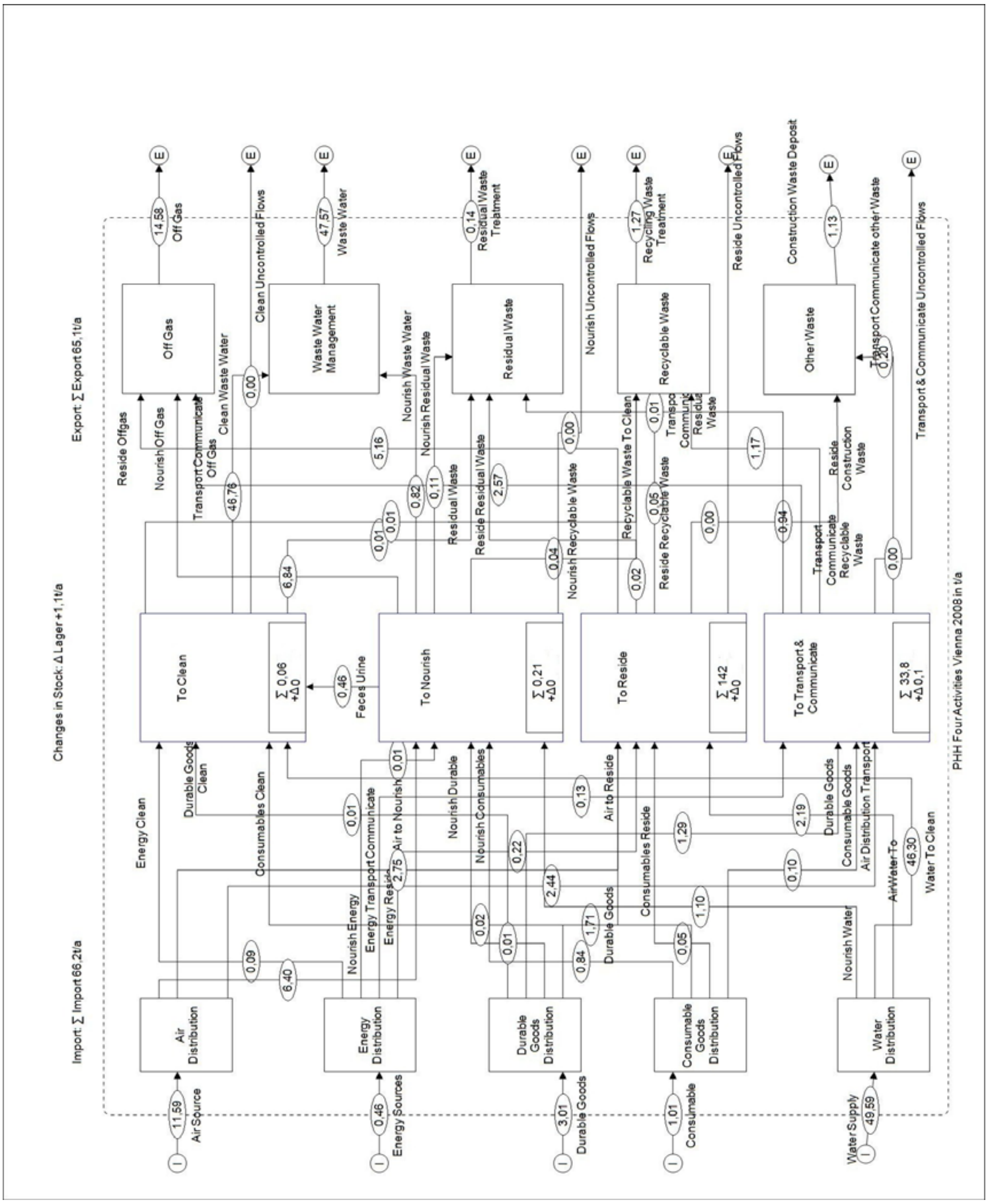
Looking at the mass of exports, the main export volume comes from the activity *To Clean* with 74%, then followed by *To Nourish* with 13% which exports as much as the other remaining activities combined.

These Exports need to be further calculated in order to determine their importance for the sinks.

In the following, a complete overview of the PHH system including the input flows separated into activities and export flows have been attempted.

Even though this system looks complicated, it is a reflection of just a tiny fraction of the complexity of the actual PHH system, but for the sake of transparency and overview, it has been reduced to this level.

It is anyway mind-boggling to think that each person in Vienna moves about 65 tons per capita annum.



Graph 4-1 MFA Summary Overview in t/a

4.1.2.1 Incineration of Sewage Sludge and Residual Waste

All residual waste as well as the sewage sludge in Vienna is incinerated. The following table shows the overview of the origin of the ash generated by the incinerators, with only 6 % from the Waste Water and the remaining 94 % from the residual waste.

Overview Cinder and Ash from Vienna Incinerators 2008 by PHH and non PHH				
Origin: Cinder and Ash from MVAs	**t/p.a.**	**PHH**	**non PHH**	% PHH
Cinder (Schlacke)	152.000,00	125.780,00	26.220,00	84,98%
Filter Ash (Filterstaub)	15.500,00	12.826,25	2.673,75	8,67%
Sewage Sludge Ash	18.800,00	9.400,00	9.400,00	6,35%
Total	**186.300,00**	**148.006,25**	**38.293,75**	**79,45%**
Source: MA 48, own estimations PHH in waste (82,75%), PHH in Sewage (50%)				

Table 4-5 Cinder/Ash from Vienna Incinerators

As for the residual waste, the percentage of 82,75% was applied for the PHH (see residual waste analysis chapter 4.1) and for the Sewage Sludge from Waste Water the percentage of 50% was applied.[18]

These cinder and ash is further treated to make it feasible for deposit (upper table), in addition, there was an amount of about 5400 tons (2008) of highly toxic waste actually exported to Germany for deposit (lower table), but as stated in the chapter 4.1., this is treated here as it would be deposited in Vienna, so we reach the numbers in the Grand Total in the middle.

Actual Processed Cinder Ash Deposits in Vienna 2008					
Deposited in Vienna	**t/p.a.**	**PHH**	Sewage Origin	Incinerator Origin	***non PHH***
Cinder/Ash Concrete	148.000,00	117.586,00	7.466,71	110.119,29	*30.414,00*
Demineralised Cinder	47.500,00	37.738,75	2.396,41	35.342,34	*9.761,25*
Cinder/Ash Mixture	8.700,00	6.912,15	438,92	6.473,23	*1.787,85*
Total Landfill	**204.200,00**	**162.236,90**	**10.302,04**	**151.934,86**	***41.963,10***
Source: MA 48 and own estimations PHH in treated cinder/ash (79,45%)					
GRAND TOTAL for PHH / tons		**47.138,75**	**11.796,41**	**35.342,40**	
Toxic Rotary Ash and Filter Cakes not deposited in Vienna 2008					
Not Deposited in Vienna (exported to Germany)	**t/p.a.**	**PHH**	Sewage Origin	Incinerator Origin	***non PHH***
Sewage Sludge Ash Rotary Furnace Simmering	2.500,00	1.250,00	1.250,00		*1.250,00*
Filter Cake all Vienna Incinerators	2.900,00	2.399,75		2.399,75	*500,25*
Total Export	**5.400,00**	**3.649,75**	**1.250,00**	**2.399,75**	***1.750,25***
Source: MA 48, own estimations PHH in waste (82,75%), PHH in Sewage (50%)					

Table 4-6 Actual Processed Cinder Ash Deposits

[18] E-mail information by Mag. K. Wögerer from the Vienna Waste Water Treatment Plant on Aug. 9, 2011

To the attribute the Sewage Origin Ash and Incinerator Origin Cinder/Ash deposited to the sink landfill, we need to revert to the Table 4.3 Overview of Exports of the Activities, where the percentages for the respective activities have been calculated.

Distribution of the Incinerator Waste to the Activities in Vienna 2008						
	PHH	Total	Sewage Origin	%	Incinerator Origin	%
GRAND TOTAL for PHH / tons	*165.886,65*		*11.552,04*		*154.334,61*	
pc.a/PHH in kg	98,73	98,73	6,88	100,00%	91,86	100,00%
To Nourish	-	**36,43**	0,18	2,65%	36,25	39,50%
To Clean	-	**6,69**	6,69	97,35%	-	0,00%
To Reside	-	-	-	0,00%	-	0,00%
To Transport	-	**55,61**	-	0,00%	55,61	0,61
Source: MA 48, own calculations						

Table 4-7 Distribution of Incinerator Waste to the Activities

Therefore, we can attribute **36,43 kg/c•a for the PHH** of landfill deposits to the activity *To Nourish*, **6,69 kg/ for the PHH** of landfill deposits to the activity *To Clean* and **55,61 kg/c•a for the PHH** of landfill deposits to the activity to transport.

As for the activity *To Reside*, the landfill volume is registered in the category other waste, where we reach **1,6377 t/c.a for the PHH** which is comparatetively much more significant than the waste from incineration.

4.1.2.2 To Nourish

The contribution of the activity *To Nourish* into the sinks is quantitatively heavily dominated by the export to the sink “air” which can be explained by the constant respiration and transpiration taking place with the process of the human body.

Contribution of To Nourish to the Sinks kg/pc.a PHH 2008							
	Air	**%**	**Water**	**%**	**Soil**	**%**	**TOTAL**
Total kg to Sinks	**6.840,00**	**83,95%**	**1.271,00**	**15,60%**	**36,43**	**0,45%**	**8.147,43**
Source: own calculations							

Table 4-8 Contribution of To Nourish to the Sinks

The export to the sink “water” of this activity is comparatively low, as it is only originated for some amount of waste water during food preparation and feces/urine.

4.1.2.3 To Clean

The contribution of the to activity *To Clean* into the sinks is absolutely dominated by the export to the sink “water” which can be explained by the enormous amount of water that we use every day, for toilet flush, hygiene, laundry, dish washing and other.

Contribution of To Clean to the Sinks kg/pc.a PHH 2008							
	Air	**%**	**Water**	**%**	**Soil**	**%**	**Total**
Total kg/pc.a to Sinks	**-**	**0,00%**	**46.756,00**	**99,99%**	**6,69**	**0,01%**	**46.762,69**
Source: own calculations							

Table 4-9 Contribution To Clean to the Sinks

Although the quantitative numbers seem high, the amount of water used and released to the Danube is not problematic, as the waste water treatment plant in Vienna is laid out for 4 million inhabitant equivalents, and has room for enlargement when necessary, we currently only utilize about 3,25 (1,8 million inhabitant equivalents in the private households and 1,45 million inhabitant equivalents in the industry). Also the supply side is secure or even underutilized as the average amount of water used per person/day has been decreasing over the last decades, coming down from about 150l/day (150kg/day) to current 130l/day (130kg/day), which creates problems for the quality of the water in summer time when many Viennese are on vacation so that sometimes extreme measure such as opening the water hoses hydrants on the Vienna streets to create a relief.[19]

4.1.2.4 To Reside

This activity is dominated by exports into the sink “air” due to heating on the one hand, and the landfill of construction waste on the other hand.

Contribution of Activity to the Sinks kg/pc.a PHH 2008							
	Air	**%**	**Water**	**%**	**Soil**	**%**	**Total**
Reside	**2.974,93**	**76,07%**	**-**	**0,00%**	**936,00**	**23,93%**	**3.910,93**
Source: own calculations							

Table 4-10 Contribution To Reside to the Sinks

As in the case of air, the contribution to the sink can be described as quantitatively non-problematic, the qualitative dimension of needs to be considered in terms of CO2 footprint or toxicity needs to taken into account, which was not within the aim of this paper.

More concern is the contribution of this activity to the sink “soil” as most of the Vienna originated volume is exported to the Bundesländer, which will be discussed in more detail in the discussion of the sink.

[19] e-mail information by Mag. Wögerer from the Vienna WWTP, 2011/08/09

4.1.2.5 To Transport and Communicate

This activity is dominated by the air consumed by the fossil energy burning vehicles used in the individual transport, and some minor contribution from the road infrastructure. Most of the road infrastructure material is recycled and reused, but about 16% needs to be landfilled into the sinks per year.

Contribution of Activity to the Sinks kg/pc.a PHH 2008							
	Air	**%**	**Water**	**%**	**Soil**	**%**	**Total**
Transport & Communicate	**2.750,00**	**93,95%**	**-**	**0,00%**	**177,00**	**6,05%**	**2.927,00**
Source: own calculations							

Table 4-11 Contribution Transport and Communicate to the Sinks

4.1.3 Contribution of the Activities to the Sinks: Summary

The following table shows the contribution of each activity to the sinks Air, Water and Soil. As discussed in the preface, this paper aims at highlighting only the quantitative mass of the contribution, not the quality of the contribution to the sinks, such as toxicity, potential energy content of waste or other.

Contribution of the Four Activities to the Sinks kg/pc.a PHH 2008							
	Air	**%**	**Water**	**%**	**Soil**	**%**	**Uncontrolled Flows**
Nourish	6.840,00	54,44%	1.271,00	2,65%	36,43	3,15%	low
Clean	-	0,00%	46.756,00	97,35%	6,69	0,58%	low
Reside	2.974,93	23,68%	-	0,00%	936,00	80,96%	high potential
Transport & Communicate	2.750,00	21,89%	-	0,00%	177,00	15,31%	high potential
Total kg to Sinks	**12.564,93**	100,00%	**48.027,00**	100,00%	**1.156,12**	**100,00%**	
Source: own calculations							

Table 4-12 Contribution of Four Activities to Sinks

As for the area of uncontrolled flows, the topics of nourish and clean seem to be quite well documented. As for the area of *To Reside*, *To Transport and Communicate*, there is a high potential of uncontrolled flows due to the incomplete data and controllability of the boundary Vienna.

Comparing these numbers with Beschorner (1996), following conclusions can be reached: The numbers are consistent except in the area, where this thesis deviates from the research question of precursor study, especially in the area of *To Reside*, where the housing infrastructure has been considered, which was omitted in the Beschorner study. In the case of Air and Water the numbers are matching.

Contribution of PHH to Sinks			
	a) Chen 2011	b) Beschorner 1996	Main Reason for Deviation
Reference Year	2008	1993	
Air	12.564,93	19.600,00	Heating Technology (Gas, District Heating), Plants in Households not considered
Water	48.027,00	52.800,00	Trend of slight decrease in Water consumption
Soil	1.736,43	420,00	Different Approach, Housing Waste not considered in b

Table 4-13 Comparison of Contribution of PHH to Sinks 2008 vs. 1993

4.1.4 Water

As The PHH uses about 130 l per day of Water, whereof some is consumed, some transpired and the remainder goes to the waste water treatment plant, but then added with rain water so that Vienna Waste Water Treatment Plant calculates the amount of **198 l of Water per day** that is treated and released to the Danube. In the following calculation, the rain water has not been considered.

Activities to Export in kg	Waste Water	%
To Nourish	1.271,00	2,65%
To Clean	46.756,00	97,35%
To Reside		0,00%
To Transport		0,00%
Total kg to Exports	**48.027,00**	**100%**

Table 4-14 Activities contribution to the sink water

In total, one person processes about 48 tons of water per year, mainly with the activity *To Clean*, which occupies about 97% of the share and the activity *To Nourish* the remaining 3%. As water is not in shortage in Vienna and the capacity of the Waste Water Treatment Plant in Vienna is not fully utilised, the sink water is, from the current point of view, not a restriction for the growth of Vienna. As a comparison, Beschorner (1996) calculates the water consumption with 55 t/pc.a for the year 1993. This number does not deviate much from the results found in this thesis.

Baccini et al. (1993: p.39) on the other hand, showed an use of 80 t/pc.a water per year, which is much higher than this thesis calculated, using the number of 220 l/pc.d for Swiss city of Sankt Gallen, whereas the Vienna Waste Water Treatment Plant gave the information that they calculate with 130l/pc.d as input from the Vienna Water Supply Works. Looking into the items, Baccini et al. (1993: p.39) calculated with 30t/pc.a (compared with 17,5t/pc.a Beschorner (1996)) for the process "hygiene" and 27t/pc.a (19t/pc.a) for the process "toilet flush".

As the Beschorner (1993) numbers matched the inputs from the WWTP and my own calculations, I have based my MFA on the lower numbers.

From the waste water treatment, a total 67.451 (Umwelterklärung 2009) tons of Dry Sewage Sludge is generated, which is then then thermally treated, the Vienna Waste Water Treatment Plant reported a total of 67.451 tons (33.725 tons PHH or 20 kg/c•a) of Dry Sewage Sludge in 2008 which was incinerated at the Rotary Furnace in Simmering, resulting in a total 18.800 tons of sewage sludge ash (9.400 tons PHH or 5,6 kg c•a).

4.1.5 Soil

The sink air is mainly strained from the activities *To Reside* (81%) and *To Transport and Communicate* (15%) and to a small extent from the activity *To Nourish* (3%). While the residual waste from the activity *To Nourish* is incinerated to reduce volume, the construction waste from *To Reside* and *To Transport and Communicate* is landfilled without thermal treatment, therefore the volume is relatively high.

The only landfill in Vienna for construction waste is in the 21st district, named Langes Feld, with current free capacity of 1,3 mio. tons and if an extension is granted, another 1,4 mio. tons would be made available[20]. Compared to the calculated contribution per head of construction waste from the activity *To Reside* and *To Transport and Communicate* of about 1,16 tons, it can easily be seen that the available sink is very limited – as it can hold one year of all Viennese construction waste - and by no means sufficient.

Contribution of the Four Activities to the Sink Soil kg/pc.a PHH 2008		
	Soil	%
Nourish	36,43	3,15%
Clean	6,69	0,58%
Reside	936,00	80,96%
Transport & Communicate	177,00	15,31%
Total kg to Sinks	**1.156,12**	**100,00%**

Table 4-15 Activities contribution to the sink soil

4.1.6 Air

The sink air is to about half utilized by the activity *To Nourish* in the form of respiration and by 24% by the activity *To Reside*, which is mainly heating, and by another 22% by the activity to communicate, which is the air needed for combustion in the car engines.

[20] E-mail information from Mr. Mrschtik, General Manager of Langes Feld on Oct. 5, 2011.

Contribution of the Four Activities to the Sinks kg/pc.a PHH 2008		
	Air	**%**
Nourish	6.840,00	54,44%
Clean	-	0,00%
Reside	2.974,93	23,68%
Transport & Communicate	2.750,00	21,89%
Total kg to Sinks	**12.564,93**	100,00%

Table 4-16 Activities contribution to the sink air

In total, 12.5 tons of air are processed per person per year and released to the sink air or atmosphere as an anthropogenic influence. If the quality in terms of toxicity, particles etc. is not considered, then the volume per se cannot be judged as a limitation to the growth of the city.

4.2 Recycling and Urban Mining

In the context of sustainability the issue of recycling and urban mining is getting more and more important. In the following, the recycling rates for selected categories and their potential future increased recycling and mining are discussed.

The following shows a rough overview of the collected recyclable waste per head in 2008 based on numbers of 2006 for the city of Vienna, with the exception of construction waste.

Recyclable Waste	**Tons**	**kg/c•a**
Paper and Board	128.622	77
Glass	25.346	15
Metal	16.407	10
Plastic Bottles	5.546	3
Small Electronic Appliances	7.890	5
Biogenic Waste	99.565	59
Total Recyclable Waste	**283.376**	**169**
Source: Fehringer and Fruehwirth (2008)		

Table 4-17 Recyclable Waste 2008

4.2.1 Recycling Rates for Construction Material

The city of Vienna has initiated the Project RUMBA (environmentally friendly construction site management) because construction sites are a main source for pollution in the City:

· Two thirds of commercial transport traffic (in tons) are related to the construction industry.

· 99 % of construction traffic is done with with trucks

· up to 10 % of NOx- and particle emissions of traffic are construction traffic

· Construction of one apartment causes 60 truck drives and is responsible for 2.500 - 3.000 kms.

· 75 % of total waste is construction waste, only one third of it is recycled.

· 13 % of Vienna population suffers pollution from construction site noise.

(BAWK 2007: p. 44)

According to the Table in the BAWP (2006: p.55) the 72% percentage of construction waste in Austria is recycled, however the Vienna BAWK (2007: p. 44) (see above) states that only one third of it is recycled, this may be due to the fact that in Vienna we see mainly residential building construction and these are the sites with the worst recycle rate of 9% overall in Austria. There is also no differentiation between PHH and non-PHH buildings.

Recyclable Construction Waste AUSTRIA 2004			
Waste Category	**Volume/t**	**Actually recycled %**	**Volume/t**
Construction Site Waste	93.000	9%	8.370
Mineralic Construction Waste	1.688.000	68%	1.147.840
Road Construction Waste	1.005.000	84%	844.200
Concrete Waste	1.034.000	76%	785.840
Railway Gravel	246.000	56%	137.760
TOTAL	**4.066.000**	**72%**	**2.924.010**
Source BAWP 2006: p. 55			

Table 4-18 Recycling Rates of Construction Material

For the purpose of this paper, the biggest quantifiable stocks in the activity of *To Reside* were identified as, concrete, bricks and steel, the estimates for the stock was 63% Bricks, 25% Concrete and 2% Steel.

Of these stocks, only concrete can be traced in the output waste: according to the BAWP-Ist (2007), the amount of 201.860 tons (data from 2005) of concrete was found in the waste.

Generally speaking, the recycling of construction waste is depending upon the possibility to separate the different construction material without contamination. This technique is called “selective deconstruction” (German: selektiver Rückbau). By applying this technique, one can secure the separation of different construction material and at the same time avoid contamination of the non-toxic fraction oft the construction material. (Scheibengraf and Reisinger 2005: p. 46) One tool to enforce that already during the construction period the later possibility of "selective deconstruction" is to tie the award of residential construction facilities (German: Wohnbauförderung) to the use of this technique.

4.2.2 Recycling of Biogenic Material

In total, we find about 67kg/c•a biodegradable material, which is separately collected and used for composting, on the other hand, still the very high amount of 106,2 kg/c•a of Biomaterial is found in the residual waste which goes into incineration.

When we discount 50% of the collected material in the separated collected biogenic waste as plants and trees from the public gardens and woods, we see even more that Vienna, as a city, has a relatively inferior collection rate of biodegradable waste material, be it for the low number of biodegradable waste containers ("Biotonnen") available in the vicinity and, as a city, the limited number of households who practice composting in their garden or backyard due to space limitation or the unpleasant odour that these Biotonnen might develop.

As biogenic kitchen waste (36%) is the predominant ingredient of residual PHH waste, here main efforts would reap immediate effects, as public awareness can be steered into the right direction if the separate waste collection of biogenic material would be more promoted in the city of Vienna.

Since autumn 2007, biogenic waste is burnt and transformed into energy – about 17.000 tons p.a. of biogenic waste is burned per year from the biogenic collection of markets and collected kitchen waste and produces biogas. The remainder is used to produce compost. The Waste water is collected and recycled, the offgas is cleaned before release. (Umwelterklärung MA 48 - 2009: p.116)

4.2.3 Recycling of Metals

The recycling rate of metals in Vienna compared to the metal content of the residual waste is still quite low, with 4,4 kg/c•a separately collected for recycling, but still a loss of 9,40 kg/c•a of recyclable metals in the residual waste, which means that only on third of the metals is collected for recycling, and two thirds are lost through incineration. As the production of materials are extremely energy intensive, major efforts should be conducted to introduce deposit systems for aluminium cans like in Germany which lie in the area of 0,15 € to 0,25 €.

4.2.4 Recycling of Paper and Board

The recycling rate of Paper and Board is quite high, but could be improved, as there is still about 48,3 kg/c•a which is to be found in the residual waste. Compared to the 81 kg/c•a found in the separate collection, we are recycling about two thirds, but still have about one third of paper and board as potential.

4.2.5 Recycling of Glass

We still find about 17 kg/c•a of glass in the residual waste, which is still too much, given that the recycling containers for glass are ubiquitous, and compared to the 15,46 kg/c•a that is recycled, this means that only less than half of the glass put into circulation is recycled. Although recycling is one way of improving the sustainability of a container, the best way to avoid the inflow to the sinks is to avoid the flow altogether. Therefore the reusable containers should be a priority for all serious waste management systems.

It should be noted that glass bottles that are destined for one-time use are comparatively not more environmentally sound than other one-way containers, e.g. aluminium cans or plastic bottles. Glass bottles win their sustainability only through their repeated use, with the rule of thumb being that after seven times of usage, the re-used deposit bottles win over the one-way containers.

4.2.6 Recycling of Plastics

Plastic Bodies, Plastic Foils and Other Plastics are estimated at around 27 kg/c•a officially, however other much higher numbers are given by documentaries as Plastic Planet (directed by Werner Boote, 2009) with gives the number of about 100kg/c•a for a France. In the knowledge of the shortage of fossil material, which is the base for the production of plastics, there is still a considerable amount available for recycling and need to make the plastic cycle more controlled, given that in 2008 only 5 kg/c•a was collected separately. Here main efforts shall be conducted, e.g. with the introduction of refundable deposits per unit like in Germany in the area of 0,15 € to 0,25 € and other legislation needed for a better control of the whole cycle

4.2.7 Other Recyclable Materials

Of the other waste, there are 9,44 kg/c•a of textiles, as in Austria, there is a quite well established network of collection for old clothes from Humana, Kolping and Caritas, therefore one can assume that the textiles in the residual waste will be mainly not usable for wearing any longer.

4.3 Uncontrolled Flows/Limitation of Study

It can be assumed that there are uncontrolled flows from each activity to each sink that have not been considered. For example, in the case of water, there is the leach into the groundwater or the overflow into the Danube that is not considered in the closed system of Vienna that ends with the Central Waste Water Treatment Plant in Simmering, Vienna.

Also, many goods are not exported when they become out of their primary use such as household equipment, furniture etc. when they are stored in the cellars or in the 2nd residence in the countryside or exported to other countries.

In the case of the activity to transport, the issue of rubber loss for car tyres or the general corrosion in the city, or the copper loss from roofs washed away by the rain etc..

To study the field of uncontrolled flows would open a vast scientific field and yield many more interesting studies on this subject.

5 Summary and Conclusion

The city of Vienna is growing at a remarkable pace, contrary to the expectations and the public image, and will surpass the 2 million mark within the next 30 years.

As the private households play a pivotal role in the development of the city, and as city like Vienna has its focus on services and not on production, the main contributor to the sinks will be the private households, as their dominance in the city system will most probably increase further.

Looking at which activity puts the most pressure on the sinks, the activities *To Nourish* and *To Clean* do not seem to be a limitation for urban growth if only looked at from the level of goods. The picture might turn if the level of substances is added, that e.g. nitrogen dissipation or a cleaning chemical will play a limiting role in the future, and that some substances that we use today and judge them as non-problematic might turn out to be highly problematic and of not sustainable use in the future.

However, in the area of *To Transport* and *To Reside* which produces mainly construction waste, which is not incinerated, the pressure these activities put to the sink "soil" is remarkable and currently only solved by exporting them to the nearby areas in the hinterland of Vienna.

In the future, if there maybe more reluctance from the hinterland to accept the export of construction waste, this may be a serious limitation for further growth as the current single deposit can hold only one or two years of the Vienna annual construction waste.

In the case of a more efficient recycling construction waste, the difficulty lies in the old residential stock of with its unclear data about the material used and the after-treatment of the stock for buildings older than 30 year, which is the vast majority. The exact building material of the stock is not well investigated; therefore it is very difficult or non-economical to undertake an increased effort in recycling.

However, new buildings must be already built with view to the later recycling process and the aim must be to reduce the construction waste dramatically, and here the legislation has to provide the necessary framework.

With respect to a better recycling rate and collection for the other waste, there is always room for improvement, especially in the case of metals, where only one third is collected and plastics, which also has a potential for improved return rates as well as not fully controlled cycles. This could be initialised through a refund system such as in Germany for beverage containers of aluminium or plastic.

As this paper is aimed at analysing the situation purely from the quantitative point of view of mass flows, a comprehensive answer to the question whether sinks are a limitation to urban growth can be only endeavoured to be given via the gargantuan task of also analysing the quality of the flows into the sinks.

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7 Appendices

7.1 Input Output Balance of MA 48 Vienna Waste Management Department

Input

Für Betrieb

Objekte- Energie und Wasser	
Strom	10.203 MWh
Fernwärme	12.844 MWh
Erdgas	757.029 m³
Flüssiggas	16.235 l
Heizöl	30.147 l
Trinkwasser	207.711 m³
Brunnenwasser	32.422 m³
Fahrzeuge- Treibstoffe	
Mineralöldiesel	7,402.220 l
Mineralölbenzin	77.760 l
Erdgas	18.144 kg
Biodiesel	70.575 l
Hilfs- und Betriebsstoffe	
Öle	102.906 l
Fette	4.657 kg
Reifen	3.322 Stk.
Farben und Lacke	2.532 l
Lösungsmittel	2.299 l
Zement	17.752 t
Papier	24 t
Batterien	8.460 Stk.
Bleiakkumulatoren	314 Stk.
Reinigungsmittel	25.494 l

Aus Sammlung / Tätigkeit

Systemsammlung	
Mischabfälle	584.878 t
Altpapier	127.817 t
Altmetall	15.253 t
Altglas	26.532 t
Kunststoffverpackungen	8.416 t
Sonstige Altstoffe	56.602 t
Kompostmaterial	118.436 t
Inerte Abfälle	75.906 t
Straßenreinigung	
Straßenkehrricht schwer	5.969 t
Straßenkehrricht leicht	28.402 t
Kunststoffflaschen/Metalldosen	315 t
Problemstoffe	
Gefährliche Abfälle	6.281 t
Kfz-Wracks	1.071 t
Müllverbrennungsanlagen	
Schlacke	150.993 t
Asche	34.137 t
Winterdienst	
Streusplitt	8.270 t
Auftausalze	35.859 t

DIE 48ER
DEIN WIEN

Output

Aus dem Betrieb

Objekte- Abfall	
Hausmüll	697 t
Papier	146 t
Metall	125 t
Glas	55 t
Kunststoffverpackungen	66 t
Altreifen	127 t
Gefährlicher Abfall	
Altöl	62 t
Batterien	112 kg
Bleiakkumulatoren	13 t
Ölabscheiderinhalte	117 t
Sonstige gefährliche Abfälle	15 t
Emissionen	
CO_2 aus Treibstoffen	16.444 t
CO_2 aus Heizung	1.777 t
Wasser	
Abwasser	592.086 m³

Systemsammlung und Straßenreinigung

Abfall	
Mischabfälle	622.458 t
Biogene Abfälle (Gärreste, Siebüberlauf)	28.158 t
Altstoffe	
Altpapier	127.677 t
Altmetall	29.043 t
Altglas	26.663 t
Kunststoffverpackungen	7.554 t
Sonstige Altstoffe	55.948 t
Inerte Abfälle	82.473 t
Problemstoffe	
Gefährliche Abfälle	8.328 t
Kfz-Wracks	1.071 t
Aufbereitung	
Schlackenbeton	213.337 t
Kompost	60.100 t
Winterdienst	
Streusplitt	5.614 t
Auftausalze	29.376 t
Energie	
Deponiegas	4 Mio. m³
Biogas	6.570 MWh

Input-Output Bilanz der MA 48 für das Jahr 2010

7.2 Recyclable and Hazardous Waste Collected in Vienna

In the Report of the Vienna Municipal Waste Management Department 2010 p. 79 we find the following table for the separate collection of hazardous or other waste:

Jahr	Holz	Sperrmüll	Bauschutt	Altmetall	Wellpappe	Styropor	Organisch (Baumschnitt)	Bildschirmgeräte	Elektroaltgeräte (Kleingeräte)	Kühlschränke	Altreifen	Textilien	Asbestzement
1992	503	17.610	22.634	7.300	1.237	29	6.173	418	7	874	307	434	0
1993	1.401	21.239	25.920	8.121	1.263	38	5.299	455	10	550	52	389	0
1994	3.412	27.664	33.069	8.934	1.396	70	6.739	504	76	544	502	355	0
1995	8.745	28.454	33.353	9.304	1.404	84	6.475	560	185	704	396	342	0
1996	12.721	24.858	40.490	10.030	1.432	66	6.153	746	182	849	721	379	0
1997	14.369	23.950	44.539	10.937	1.443	61	6.501	723	202	1.007	792	350	0
1998	15.618	22.924	51.276	10.969	1.493	59	5.985	742	222	865	898	32	0
1999	18.592	24.854	55.599	12.056	1.763	64	7.589	888	288	905	1.048	0	0
2000	19.691	23.823	56.744	12.521	1.843	70	7.775	794	360	980	1.071	0	0
2001	19.815	24.633	56.031	12.787	1.701	74	7.318	742	426	980	1.046	0	0
2002	21.309	22.424	56.590	12.692	1.693	67	9.515	738	529	910	1.157	0	0
2003	25.306	30.378	64.259	13.018	1.762	78	9.364	890	801	947	1.342	0	0
2004	29.460	31.207	68.756	14.394	1.851	78	11.745	1.112	163	977	1.276	0	0
2005	31.487	27.726	69.720	14.371	1.870	84	11.069	1.384	314	1.256	1.282	0	0
2006	31.059	25.392	75.789	14.608	1.955	80	13.695	1.575	598	1.554	1.243	0	0
2007	35.281	22.712	74.113	13.648	2.051	86	13.148	2.016	969	1.410	1.273	0	115
2008	36.733	20.936	70.990	13.495	2.119	87	15.916	2.228	1.119	1.503	1.285	0	126
2009	40.283	14.619	67.190	15.237	2.162	82	17.518	2.407	1.250	1.555	1.245	0	158
2010	38.735	15.983	67.071	14.261	2.372	86	15.804	2.375	1.281	1.274	1.267	0	233

Gesammelte Altstoff- und Problemstoffmengen auf den Mistplätzen 1992-2010 in Tonnen

7.3 *Waste Treatment in Vienna*

Abfallbehandlung

	Durchsatz	abgetrennte Fraktion	weiterer Entsorgungsweg
Abfallbehandlungsanlage			
Behandlungsanlage für Verbrennungsrückstände	159.797 Tonnen Verbrennungsrückstände	Rückstände pro Tonne verbrannten Müll: ca. 270 kg Schlacke ca. 27 kg Metallschrott ca. 28 kg Kessel- und Filterasche ca. 1 kg Neutralisationsschlamm	Metallschrott – Verwertung Asche und Schlacke als Asche-Schla-cken-Beton – Deponierung
Kunststoffsortieranlage	8.596 Tonnen Kunststoffverpackungen 4.642 Tonnen Papier und Kartonagen	4.681 Tonnen Stör- und Wertstoffe 3.022 Tonnen stofflich verwertbare Kunststoffe 1.043 Tonnen thermische Kunststofffraktion 4.492 Tonnen Papier und Kartonagen	Thermische Behandlung, Verwertung Verwertung Thermische Verwertung Verwertung
Kompostaufbereitungsanlage	107.882 Tonnen, davon: 69.133 Tonnen aus Biotonne 38.749 Tonnen aus Mulden (Strukturmaterial) 9.952 Tonnen aus Siebüberlauf	1.750 Tonnen Stör- und Wertstoffe	Störstoffe – Thermische Behandlung Wertstoffe – Verwertung Kompostrohmaterial – Kompostierung
Aufbereitungs- und Sortieranlage für Haus- und Sperrmüll	115.886 Tonnen	2.961 Tonnen verwertbare Metalle 89.956 Tonnen für WSO4 4.591 Tonnen in Ballen zur Zwischenlagerung 8.933 Tonnen Siebüberlauf 4.668 Tonnen Schwerfraktion	Verwertung Thermische Behandlung Thermische Behandlung Thermische Behandlung Mechanisch Biologische Behandlung
Behandlung von Elektro- und Elektronik-Altgeräten	3.948 Tonnen gem. EAG-VO: 160 Tonnen Altkühlgeräte 2.328 Tonnen Bildschirmgeräte 38 Tonnen Gasentladungslampen 632 Tonnen Elektrogroßgeräte 789 Tonnen Elektrokleingeräte 450 Tonnen nicht gem. EAG-VO	2.176 Tonnen Bildschirmgeräte 189 Tonnen Kühlgeräte 1.748 Tonnen gefährliche Abfälle 88 Tonnen Kunststofffraktion 198 Tonnen Wertstoffe	Wiederverw., Mechan. Behandlung Therm. Behandlung, Verwertung, Chemisch Physikalische Behandlung Thermische Behandlung Verwertung
Zentrale Problemstoffsammelstelle	804 Tonnen Problemstoffe, davon 323 Tonnen nicht gefährliche Abfälle		Thermische Behandlung, Verwertung, Chemisch Physikalische Behandlung Verwertung
Bahnverladestation - Umschlag	2.802 Tonnen Glas 3.891 Tonnen Kartonagen in Ballen 20.108 Tonnen Schrott		Verwertung Verwertung Verwertung
Umschlag per LKW	4.871 Tonnen Schrott 2.421 Tonnen Unbehandeltes Holz 6.819 Tonnen Behandeltes Holz 3.606 Tonnen Glas (Verpackungen) 7 Tonnen Flach- und Verbundglas 9 Tonnen Styropor 26 Tonnen Altreifen		Verwertung Verwertung Verwertung Verwertung Verwertung Verwertung Verwertung
Massenabfalldeponie Rautenweg	311.000 Tonnen Abfälle auf die Deponie gebracht	davon 105.000 Tonnen ausgelagert bzw. aus-sortiert (ca. 34 %)	
Verfestigte Rückstände der Müllverbrennung	175.000 Tonnen		Deponierung
Bauschutt von den Wiener Mistplätzen	35.000 Tonnen	17.000 Tonnen Eigenverbrauch (Wegebau) 12.000 Tonnen an externe Verwerter (Baurest-massenrecycling)	Rest – Lagerung
Hausmüll von Wiener Haushalten u.ä.	28.000 Tonnen	11.500 Tonnen 16.500 Tonnen Hausmüll balliert	Thermische Behandlung Ballierung
Sperrmüll	20.000 Tonnen	20.000 Tonnen zerkleinert und zur Fernwärme verbracht	Thermische Behandlung
bestimmte Fraktion von losen Schlacken (Überlauf)	18.000 Tonnen für spätere Aufbereitung zwischengelagert		Lagerung
Deponiegasverstromungsanlage	7,7 Millionen Kubikmeter Gas	elektrische Energie für etwa 3.000 Wiener Haushalte	
Kompostwerk	109.548 Tonnen Kompostrohmaterial (aufbereitet) 2.909 Tonnen Gärrest	44.769 Tonnen gesiebter Kompost 20.044 Tonnen Siebüberlauf 674 Tonnen Reststoffe	Verwertung, Rückführung (ABA) Thermische Behandlung, Verwertung

(Umwelterklärung MA 48 2009: p.36) shows the detailed numbers of the Waste Treatment