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Description of carbon flows in waste management in terms of quality and type of materials.

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Summary

This idea has been explored in the context of an MFA/SFA project called "Austrian Carbon Balance Model" (ACBM). In Material Flow Accounting (MFA) or Substance Flow Analysis (SFA), flows are generally described as aggregates of all types of materials or as single substances. However, for the connection between Production and Waste modules and for the modelling of the landfill, incineration and separation processes a conversion of the information from "types of waste" to "types of materials" was necessary. We obtained two pictures of the carbon flows from waste generation to emissions to the environment and carbon storage: "per type of waste" and "per type of material".

For the description "per type of waste" the carbon flow was divided into "Dangerous Waste", "Building Waste", "Household waste not separated" , "Separate collection from households" , "Non-Dangerous waste from industry". This rough information on the "quality" of the carbon flow was useful for a better understanding of the way different wastes are treated in the waste management chain and for future development of scenarios. It gives us information on the potential for recycling. We also divided the carbon flows according to defined classes of materials, namely, "Chemicals", "Paper", "Wood", "Plastics", "Organic Waste", "sludge" and "Minerals and Metals". This information gives us insights on possible optimisations, showing the inadequacies of our treatment of materials. Such information could help us develop a real management of materials along the waste treatment chains to avoid destroying too early their useful qualities.

Thanks to the access to data in Austria on waste management and the multiplicity of studies in the domain, it was possible to follow and describe the flows of waste in waste management for different type of waste and for different types of material

ACBM project

This idea was developed within the Austrian Carbon Balance Model (ACBM) (Orthofer et al. 1997, Jonas et al. 1997, Orthofer et al. 1999). This project developed in the context of the international discussions on climate change, possible shortcomings of the methodology and Kyoto target. According to the protocol, Austria aims at a reduction of 13% of greenhouse gases from the basis year 1990 until the period 2008-2012. The problems of climate change and greenhouse gas emissions require a global vision of carbon flows to avoid a transfer of problems from one sector to another. To tackle this problem, the methodology of ACBM has been developed by three institutes, the Institute for Industrial Ecology, the Austrian Research Centre Seibersdorf and the Joanneum Research Centre. The method developed has formed a basis for new ways of modelling carbon fluxes as an alternative to traditional methods of greenhouse gas emission inventories which only summarise emissions from different source categories. The Austrian Carbon system is divided in different modules, on one hand the "national" modules which include Agriculture, Forestry, Production & consumption, Waste Management and Energy transformation & use, on the other hand the external modules which include Import-Export, Atmosphere and Lithosphere. In the last phase of the project, flows are modelled between the years 1990 and 2010.

The waste management module

The present analysis is based on the work done within the waste module of the ACBM project. This module includes the following subsystems: "Waste Collection" , "Mechanical Biological Treatment" (MBT), and "Water treatment". "Composting" is assigned to the Agriculture module, "Incineration" to the module Energy and "Recycling" to the Production and Use module. Although for reason of consistency of this presentation, these subsystems will still be considered.
The carbon contained in waste may follow different paths. The carbon might be recycled, going to production or composting, or it might be incinerated or landfilled, possibly after an intermediate Mechanical-Biological Treatment. The carbon in the incinerators is emitted in the atmosphere as CO2, while the Carbon landfilled is stored and partially emitted in the atmosphere in the form of CO2 or CH4. The carbon composted is stored in the soil or emitted as CO2. The carbon contained in the waste water is either emitted in the atmosphere, mainly as CO2, emitted to the Hydrosphere or joins the other wastes collected from the production and consumption processes. The flows within the waste module and with other modules and the different sub-systems are shown on the next figure.
The waste management is characterised by a mix of materials as opposed to other modules. In Material Flow Accounting (MFA) or Substance Flow Analysis (SFA), flows are generally described as aggregates of all types of materials or as single substances. Deeper information on the carbon flows in waste management have been here developed: two types of description are made in parallel, the description "per type of waste" and the one "per type of material".

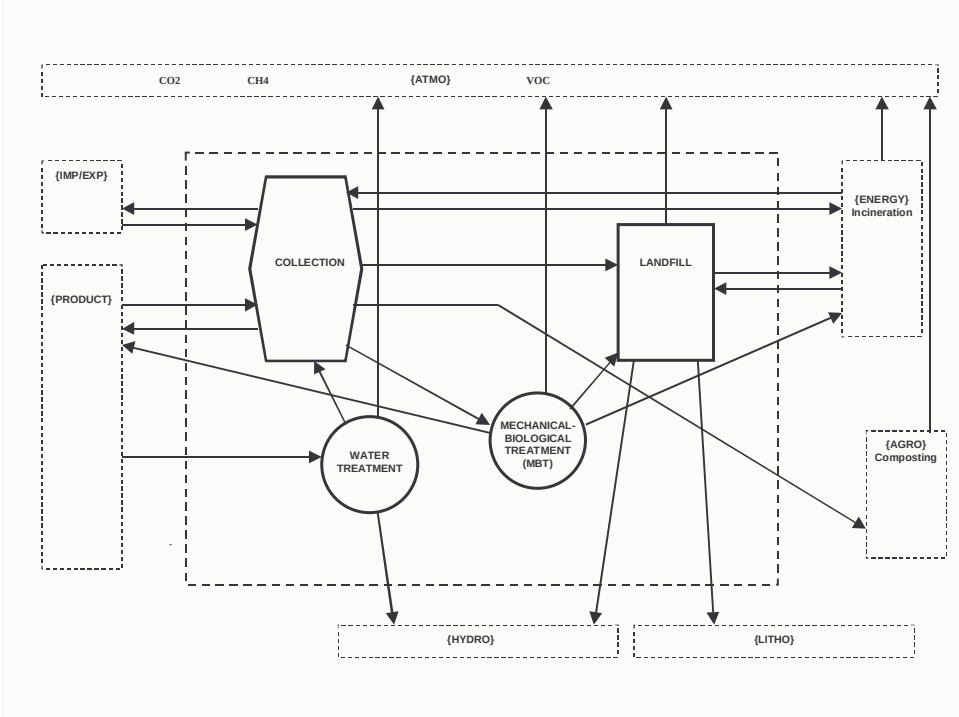

Figure 1: Waste module, subsystems and carbon flows within the waste module and with other modules

Description “per type of waste”

Types of waste include “Separate collection from households”, “Non-Dangerous waste” and “Dangerous Waste” from industry, “Building Waste”, “Household waste not separated” (Residual and Bulky waste). There are several reasons for considering this information:

- The description “per type of waste” correspond to the usual classification of waste flows in waste management.
- The types of wastes relate with the reality of the waste treatment, the way how different wastes are treated in the waste management chain
- This information is important to understand the waste module for future development of scenarios.
- It enables a disaggregated view of the data, and creates a easier understanding of the carbon flows.
- The types of waste give us some information on the potential for recycling. Carbon in a highly reusable material is not the same as carbon in a mixed waste.
- This description gives us an idea of the carbon “quality”, as different types of wastes have different level of mixing.

This analysis could be developed further and could offer interesting information as changes of quality are linked to loaded "ecological rucksacks".

Description “per type of material”

The information on the carbon flows in terms of materials, namely “Chemicals”, “Paper” (and other cellulose fibres), “Wood”, “Plastics and rubber”, “Organic Waste”, “Minerals and Metals” and “Sludge”.
This information is useful for several reasons:

- It enables a link with the production, as production flows are classified per sector corresponding to a large extent to different materials. The waste data is structured along

"types of waste" and not by waste producers. Also the separation is not always clear between production waste and trade & distribution waste.
- It enables modelling of the landfill, incineration and MBT processes.
- Information on carbon in terms of material type gives us insights on possible optimisations, showing the inadequacies of present treatment , when so much more of valuable materials could be recycled, reused many times. Flows in terms of carbon qualities could help us to develop a real management of materials along the waste treatment chains to avoid destroying too early the qualities of the materials, or to consider an improved treatment.

Method

The flows between the waste management subsystems are obtained from the waste statistics collected by Umweltbundesamt, the Austrian Environmental Agency (Krammer, Domenig et al.. 1995, Krammer & Perz 1998, Dreier 1998, Domenig et al. 1998...). This agency publishes reports every 3 years, in which the waste flows are estimated in the context of a waste management plan. In addition in 91, waste data was issued per sector with the so-called "Branchenkonzepten". Waste data are also gathered per region often on a yearly basis. Wastes are classified in a list of waste, the "Waste-catalogue" which contains around 800 types of wastes at different levels of aggregation. The most relevant level of aggregation for our purpose was identified. And an appropriate list of waste was developed, completed by important additional information gathered in different sources (Baumeler et al. 1998, Krammer et al. 1992...). Composition of each waste, the origin, the actual handling and the possible optimisations were collected. For each waste the water content and the carbon content are obtained from experts or derived from the constituents of each waste flow. The flows in and out of the subsystem "Waste collection" could then be described for the three years 92, 95 and 98 covered by Umweltbundesamt.

The different types of waste are composed of different types of materials. All this information could be used as a base for the description per type of materials. Different wastes have a different degree of mixing. Separated wastes coming from consumers include paper, organic waste and plastics, and lower amounts of metals, wood and textiles. Organic wastes includes the separately collected biowaste, and the amounts collected for home composting (eigenkompostierung) as well as the amounts from kitchen and restaurant waste, the green waste and the waste from markets that are collected. For these wastes, the impurities are handled like residual waste from consumers, and for the rest the allocation per type of material was straightforward. Other non dangerous and dangerous wastes include all the wastes coming from industry without building wastes and wastes similar to household wastes. In most cases these wastes could be easily classified as types of material. Building waste includes construction wastes, the demolition waste, (these two waste flows are a mix of many materials) the wastes from road demolition, and the structural timbers. Most of these wastes come from a long use. The composition of construction and demolition wastes is obtained from Baumeler et al and Umweltbundesamt. Residual and bulky wastes are also a mix of many materials. These include the residual waste from households, the bulky wastes, as well as street wastes. The composition is given by Umweltbundesamt.

The carbon flows are also followed in further processes. A calculation of the flow per material is achieved for the landfill and for the MBT. Data from Baumeler & al are well as simple modelling are used for this purpose. A simple model is necessary for landfill emissions and for the MBT process using then the data waste composition. The very stable materials like

plastics and lignine (from wood) will be considered as non degradable in the context of this study. They represent a type of carbon storage.
For the landfill, we assume that the cellulose and hemicellulose degrades to 50%. The swedish sources (Björklund, Sundqvist et al.1997) consider a degradation of 70% in 100 years. We assume that fat and oils, proteines, easy carbohydrates degrade to 100 % in our time scale. According to the swedish sources, we consider that cellulose/hemicellulose transform to 59% in CO2 and 41% in CH4, other molecules are found in the next table.

	in 20 years	in 100 years	CO2(%)	CH4(%)
Lignine	0	0	0	0
Cellulose/hemicellulose	50	70	59	41
Easy carbohydrates	100	100	50	50
Fats	100	100	28	72
Proteines	100	100	49	51

Table 1: Rate of degradation depending on the time scale considered and share of CO2 and CH4 in air emissions in the transformation of the different molecules
Source: Björklund

%	C-Paper*	C-Organics*	C-Textiles*	C-wood *	C-Fat & oils **
Lignine	26,37	9,73	3,05	30,00	
Cellulose/ hemicellulose	40,70	30,97	35,78	59,00	
Easy carbohydrates	0,17	37,58	0,07	1,10	6,06
Fats	1,55	6,92	0,60	7,70	93,94
Proteines	0,22	13,74	3,22	1,30	

Table 2: Carbon composition of different material in terms of organic molecules, sources: *Neumeyer, **Björklund

The mechanical biological treatment for municipal residual waste is taken into account. The residue is split in two fraction. The light fraction (diameter>60mm) is incinerated, while the heavy fraction is composted. The compositions are given by Baumeler et al. We consider a maximum degradation in the MBT composting.

We consider that only CO2 is produced by composting. For agricultural use of organic waste and other composting, we considered in the simple model here that 24% of the carbon is emitted in the form of CO2 (Amlinger 1993). For the simple incineration model, we consider that 2% of carbon incinerated goes to slags, the rest being emitted in the form of CO2. Carbon in waste water is obtained from carbon mass balances of Habersatter et al. (1998) for water treatment. 10% of the methane emitted in landfills biogas is supposed to be collected for energy recovery.

In this model the CO2 of biological origin is taken into account. A complete picture of the problem should take into account the whole ACBM system. We only show here part of the picture. Especially, the benefits of producing energy, raw materials and fertilizers from waste instead of virgin materials, is not presented in the present article. Similarly the transport, and further ecological rucksacks linked to waste management are not dealt with. Unknown and medical wastes are not taken into account. The modelling of the years 1990-2010 using this information is done at a later stage of the project.

Results

*Per type of waste

Results are presented for the year 1995 with a 20 years horizon for the landfill model.

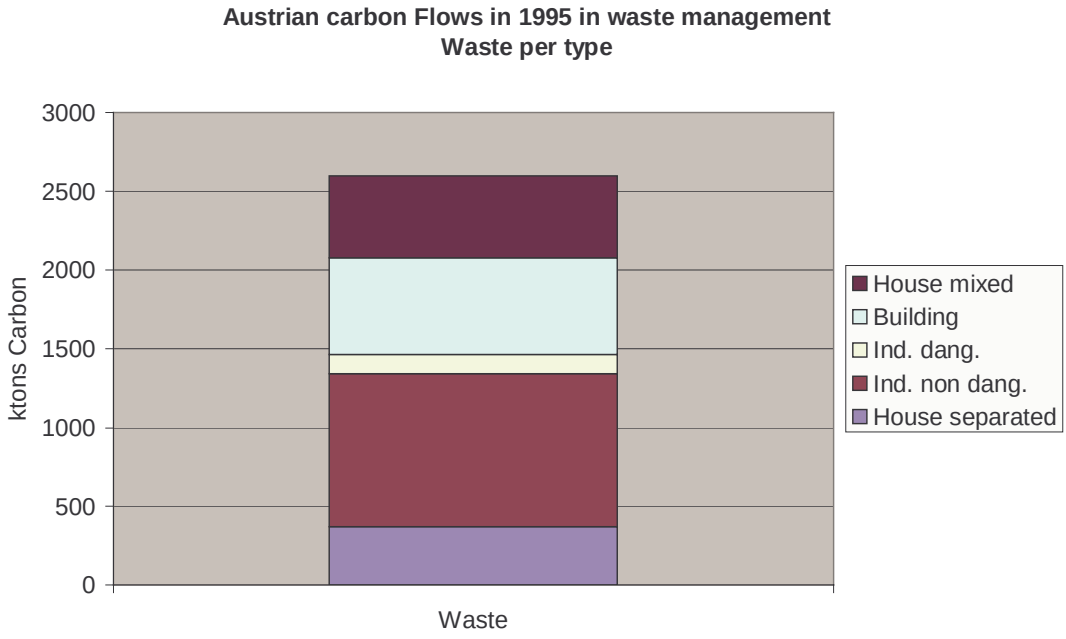

Figure 2: Amounts of carbon in different types of waste in 1995 in Austria in ktons.

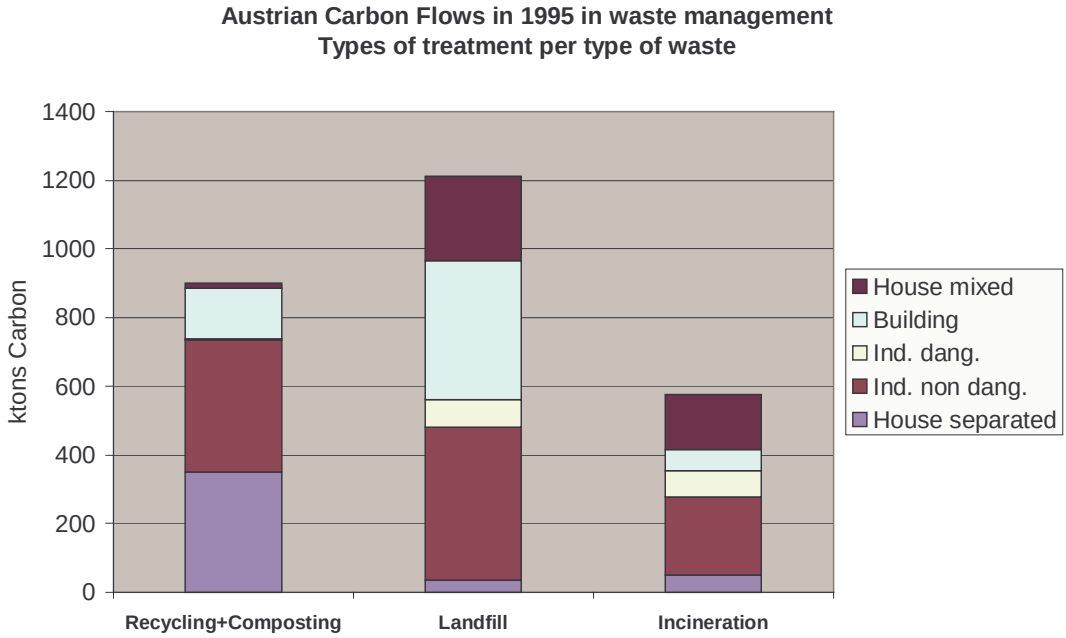

Figure 3: Waste handling for different types of waste in Austria in 1995 (ktons C)

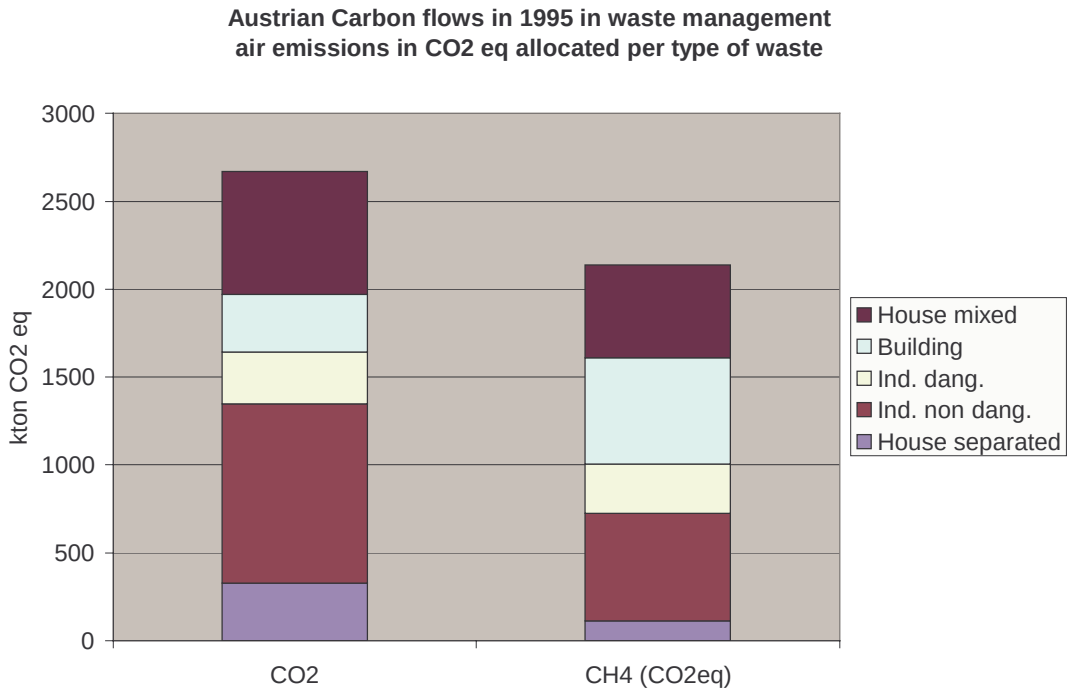

Figure 4: CO2 and CH4 emissions from the 1995 Austrian wastes with a 20 years horizon in CO2 equivalent

*Per type of material

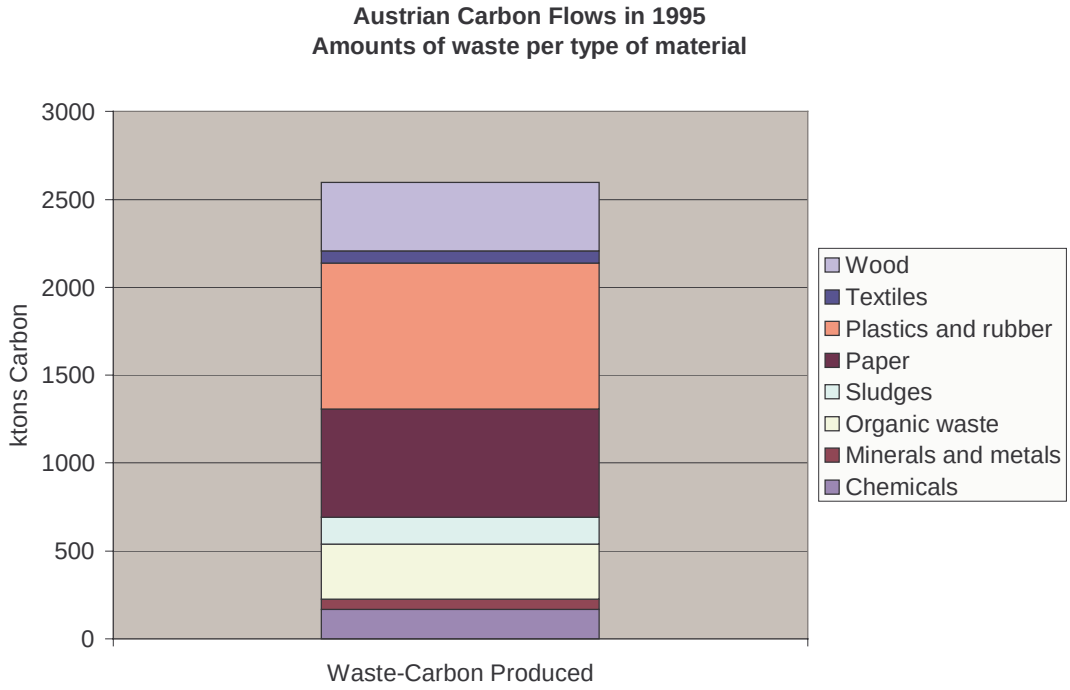

Figure 5: Amounts of waste produced in Austria in 1995, detailed per type of material, measured in kt Carbon. Important sources of carbon waste in Austria may be identified

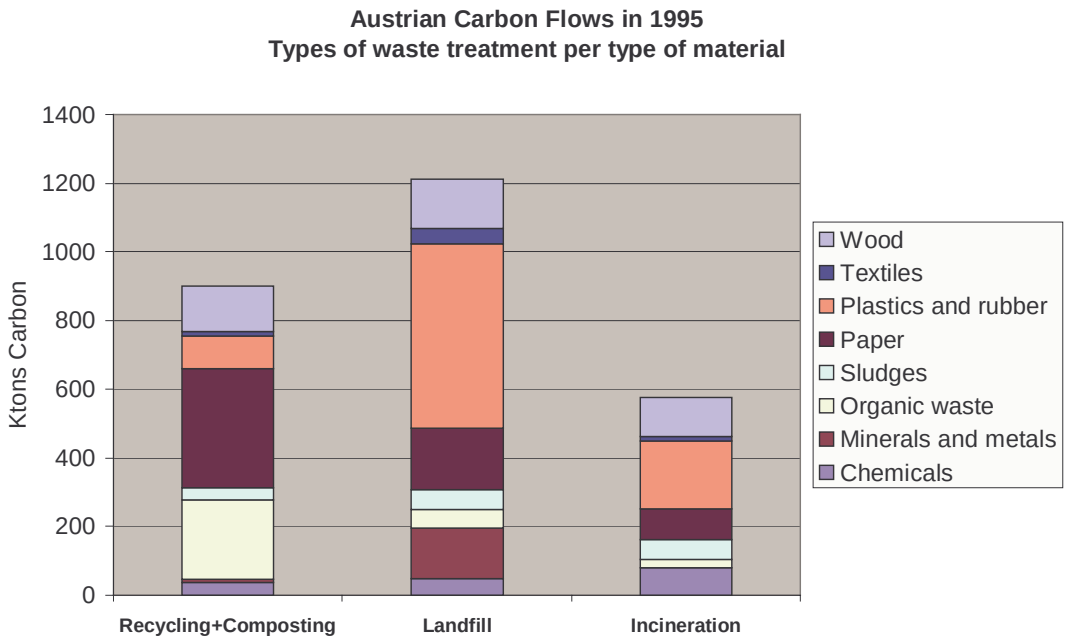

Fig 6: Amounts of carbon from each material going to different waste treatment in Austria in 1995, measured in kt carbon.

The inappropriate waste handling can be identified

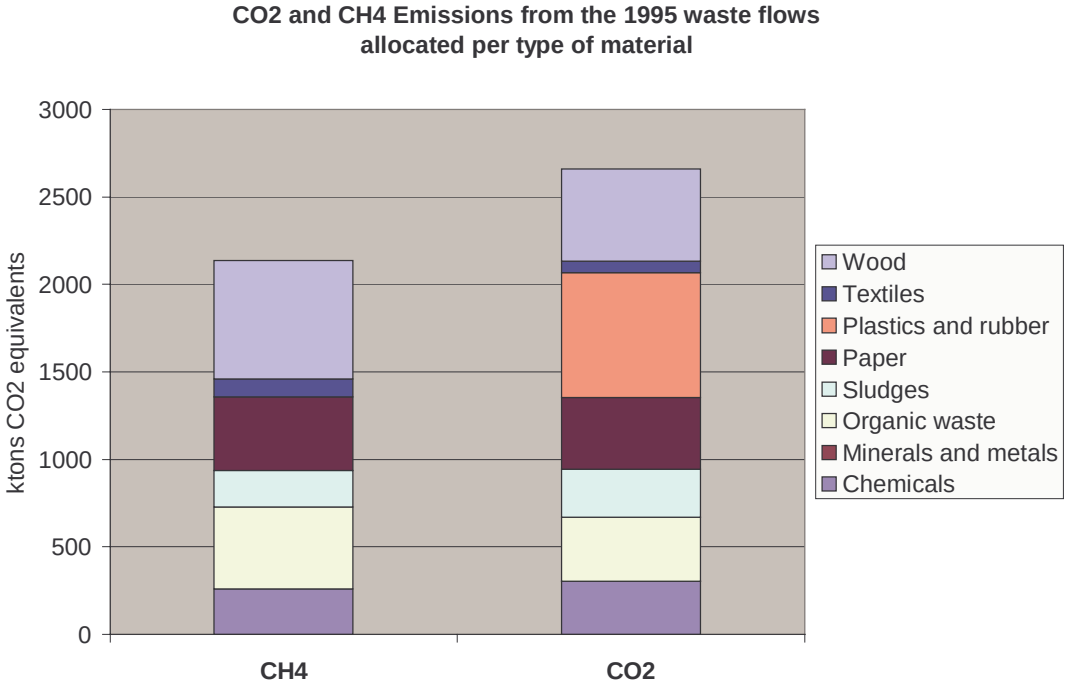

Fig 7: Emissions of CH4 and CO2 linked to waste treatment in Austria in 1995, measured in kt CO2 equivalent.The impacts linked to different types of materials may be identified

*Total carbon flows

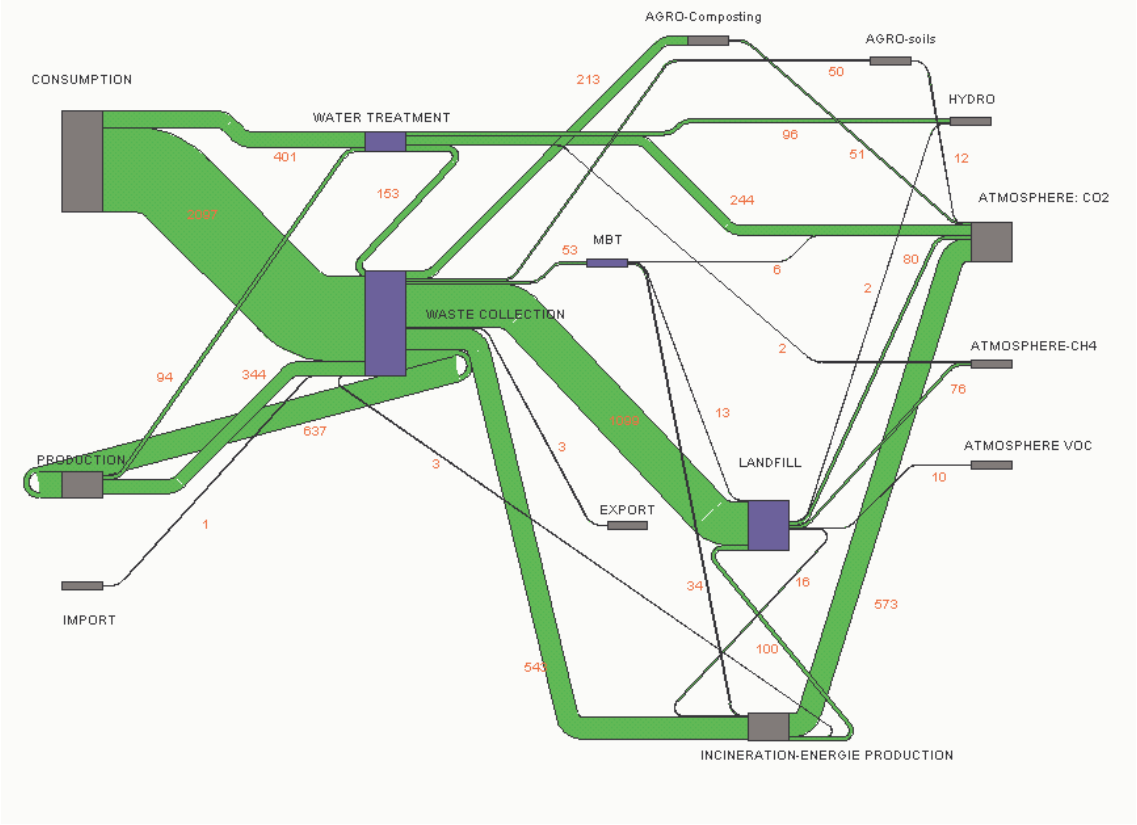

Figure 8: Total carbon flows in the Austrian Waste Management system, year 1995, kt Carbon

*Carbon from organic waste only

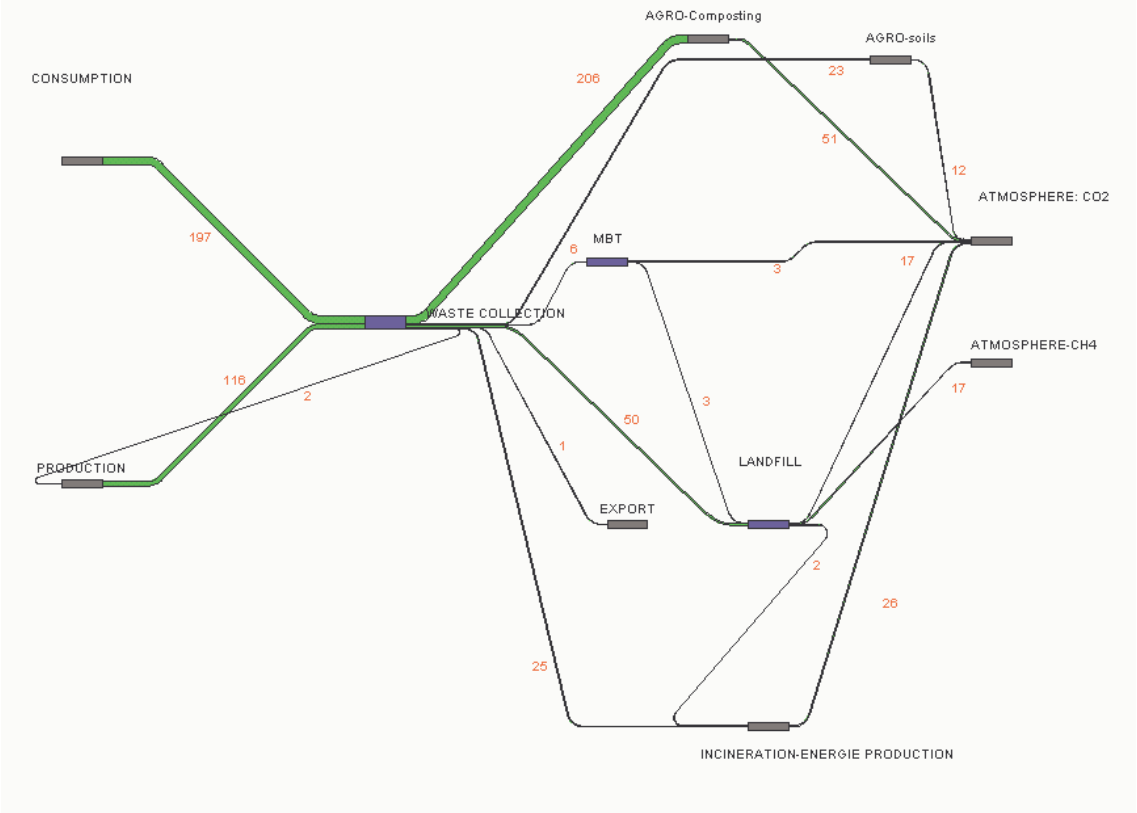

Figure 9: Share of Organic waste in the waste flow (kt Carbon).

***Carbon from households organic waste only**

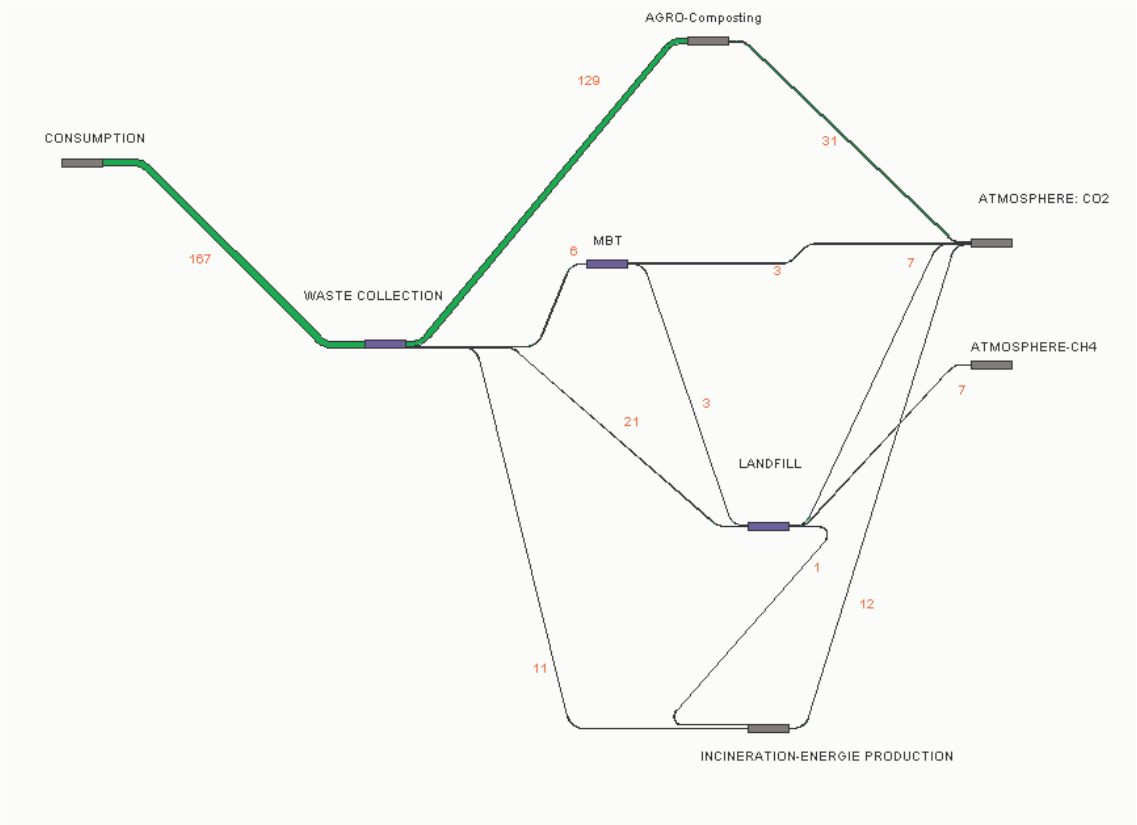

Figure 10: Share of organic waste in household waste (kt Carbon).

Combination of information on qualities and on type of material need to be developed further. It gives insights on possible optimisations, showing possible inadequacies of present waste treatment of materials and crucial points for improvement. Flows in term of qualities and characteristics could help us develop a better management of materials along the waste treatment chains to avoid destroying too early their useful qualities.

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