STATISTICS
DENMARK

Waste, Material Flows and Physical Input-Output Tables

- Input-output based waste accounts for Denmark 1999

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Contents

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Summary

This paper shows how accounts for solid waste can be established as satellites to the national accounts within a framework of physical supply-use tables (built on the principle described in SEEA 2003 (Integrated Environmental and Economic Accounting, United Nations et. al., 2003) and how the accounts can be related to physical input-output tables as well as to MFA, Economy Wide Material Flow Accounts (cf. Eurostat, 2001).

The method and the basic data sources used for this study are more or less the same as the one used for the regular production of Danish monetary input-output tables (cf. Statistics Denmark, 2004).

The paper presents the results of calculations for Denmark 1999. First an 8-industry by industry (preliminary) physical input-output table for the Danish economy is presented. The table shows - in addition to the flows of products - the flows of residuals from the economy i.e. solid waste, carbon and sulphur from air emissions and other residuals (water evaporation, etc.).

Secondly, the concept of DMI, Direct Material Flow, in relation to the physical input-output table and the accounts for solid waste generation, is highlighted. Thus, the gap between very broad methods used for economy-wide material flow account (MFA) on one side and the more detailed "traditional" statistical information on waste flows as well as physical input-output tables is bridged.

In addition to the physical input-ouput table for all materials 9 physical material balance accounts for the following product groups are presented: Paper, glass, plastic, food waste, iron and metal products, rubber, wood products, lubricating oil, and miscellaneous products. For each product group physical input-output tables at an 8-industry classification as well as overall material balances at a 26-industry classification were established. These 9 material balance accounts were compared to – and supplemented with information from - the Danish waste statistics. The result is a complete breakdown of the waste statistics at 26 industries and 18 fractions of waste.

For the above-mentioned product groups, it seems appropriate to use directly the material surpluses, which can be estimated on the basis of the physical input-output tables and material balances to the waste statistics. Generally, this approach seems to give a good view of the actual composition of the waste, since large composite fractions like *waste suitable for incineration* can be broken down by more specific fractions (paper, wood, etc.).

However, for some groups of waste, the material balance approach leads to a misallocation of the waste with respect to which industries and households generate the waste. This is a problem especially in relation to the allocation of waste from packing materials. The industries buying the packing materials and not the industries and households, which discard the packing, are accounted for as the source of the packing waste. However, with some effort it will be possible to correct this misallocation.

Other subjects for improvements of the waste accounts presented here would include better accounting for the accumulation and scrapping of materials, e.g. by including data on life cycle of products into the accounting. A better representation of the recycling and treatment of waste would be useful as well.

1 Introduction

This paper shows how accounts for solid waste can be established as satellites to the national accounts within a framework of physical supply-use tables (built on the principle described in SEEA 2003 (Integrated Environmental and Economic Accounting, United Nations et. al., 2003) and how the accounts can be related to physical input-output tables as well as to MFA, Material Flow Accounts (cf. Eurostat, 2001). The work builds upon the method used previously for constructing physical input-output tables for Denmark (Gravgård Pedersen, 1999) but contrary to that work the present work focuses on the residuals of the economy and especially the solid waste generation.

Further, it is the aim to show how far the material balance principle can be used for an industrial allocation of certain types of solid waste in the light of missing direct information.

Waste statistics and waste accounts

So far, the Danish waste statistics provide only coarse information concerning which industries generate the solid waste. The existing waste statistics are mostly concerned with describing the characteristics of the solid waste that is generated and the treatment of the solid waste e.g. whether it is reused, burned, etc.

Model for waste generation based on material balances

Contrary to statistics on solid waste the waste accounts are linked to the national accounts. This means that a breakdown of the waste generation according to national accounting industries is introduced. Since no direct statistics on the waste generation by national accounting industries exist, the production of accounts for waste must rely on estimations based on the waste statistics as well as on supplementary information.

2 Estimating materials and waste flows[1]

Method for industrial breakdown

The method used for an industrial breakdown of parts of the waste statistics is based on the construction of material balances for industries and households for selected groups of products. Physical input-output tables for the Danish economy are constructed for relevant product groups in order to illustrate the flows within the economy, and to explain the emergence of material surpluses, which lie behind the waste generation.

Material balance principle

The material balance principle is based on the fact that materials and energy do not disappear regardless of the physical processes in which they are a constituent part. Thus, if there is a physical flow into a system (production process, enterprise, industry, economy, geographical area, etc.), a counterpart must be found either in the form of an accumulation of materials/energy in the system or a flow out of the system.

It is a fundamental principle of accounting that there should be a balance of input (Danish resources, production and imports) and output (accumulation, exports and residuals/waste) for the economy as a whole. For the individual industries (and households), it must also be the case that the flow of materials into an industry (or households) must be precisely matched by a corresponding accumulation and/or flow from the industry (or households).

Product balances

The starting point used here for construction of material balances for the industries and households are the product balances (supply and use tables) of the Danish national accounts. Product balances are made up by Statistics Denmark in monetary terms (1000 DKK) on a yearly basis for approx. 2200 products. Each product balance describes the supply (domestic output + imports) and the use (intermediate

[1] This chapter is partly based on chapter 4 in Gravgård Pedersen (1999)

consumption and final demand) of the product at a detailed level (e.g. 130 industries).

By combining the monetary product balances with information on corresponding physical quantities, a picture of the physical flows (in kilogrammes) of the products can be drawn.

Drawing up of product balances in weight

From DKK to kg

The first step is a conversion of the product balances (supply and use tables) of the national accounts from DKK to kg. For each of the product balances, both the supply side and the use side are thus drawn up in kg.

Production

The compilation of domestic production in kg broken down by industry is primarily based on Statistics Denmark's production statistics.

Imports and exports

As far as imports and exports are concerned, information on imported and exported quantities from the foreign trade statistics is used.

Conversion from other volume measures to kg

In the case of a number of items in the product balances there is no information in the product statistics on weight, and this is, therefore, estimated in another way. In those cases, where alternative quantitative information has been provided, for example, cubic metres, a conversion is made from the density to kg. In other cases, the quantities are estimated on the basis of value and corresponding unit volume price. As price and quantitative information is available for exports in almost all product balances in the foreign trade statistics, the unit volume prices are typically calculated on the basis of the proportionality between the basic price and the weight of the exported item.

The use side

On the use side, it is only, as a rule, exported commodities for which there is direct statistical quantitative information. Thus, for the bulk of the use items the quantities are determined by allocating the difference between total supply and the directly-known use (exports) on the basis of the value of the relevant use drawn up at basic prices. By these means, the overall use also balances with the overall supply as far as the quantities are concerned.

Table 1 shows, as an example, the monetary and physical product balance for newsprint. In this case all newsprint is imported. For products with Danish production as well, the product balances include information on which industries produce the product.

Example of product balance

Table 1. Product balance for newsprint – Denmark 1999

	Basic price	Weight
	Mill. DKK	Tonnes
Supply		
Domestic production	0	0
Imports	1 043	268 782
Total supply	**1 043**	**268 782**
Use		
221200 Publishing of newspapers	458	118 356
221309 Publishing activities , excl. newspapers	32	8 373
222009 Printing activities etc.	540	139 357
Changes in stock	9	2 394
Exports	3	302
Total use	**1 043**	**268 782**

Uncertainty

When allocating use on the basis of (basic) values it is assumed that a kg of the relevant goods item has the same price irrespective of the category of use. This is, of course, not always the case, especially since most of the product balances cover heterogeneous groups of commodities where there is no such uniformity. Whereas the overall weight of use is thus known with reasonable certainty, there is greater uncertainty concerning the breakdown of use on the different categories.

Special Volume Item

For some products inconsistencies in the available statistics on the weight of products are apparent. Thus, in some cases the supply of a product is insufficient to cover the exports of the same product. In these cases a negative special volume item (SV) has been introduced in the physical product balances. Thus, in the physical input-output table presented in this paper, this item summarises apparent inconsistencies in the data used.

Accumulation

Since the use for final demand includes the stock changes and capital formation, the accumulation of products in the economy is, in principle, covered by the product balances. However, since the capital formation concept relies on the national accounts definition, certain types of accumulation might fall outside this concept. First of all, this is relevant for durable products acquired by the households. Also small tools etc. used as inputs to the industries might be accumulated even though it is accounted for as intermediate inputs in the table.

If scrapping of previously accumulated equipment takes place the accounts will underestimate the amount of waste generated.

For product groups, where it can be assumed that the average life cycle of the products is less than one year, it is reasonable to assume that no substantial accumulation or scrapping of products accumulated in previous periods take place.

Supplementary information on resources and recycling

Natural resources

A number of products have their origin in nature, such as crops, crude oil, natural gas, stone, sand and fish. The product balances thus cover a number of exhaustible and renewable resources, but the balances cover only the flows between industries and between industries and final demand. Thus, the product balances of the national accounts describe the flows of materials *after* they have entered the economy.

Additional information is therefore needed on the flows of natural resources from the natural environment to the economy. The resources in question are: fossil energy (oil and natural gas from the North Sea), stone, gravel, clay, etc., and also nature's direct contribution to biomass growth in connection with the production of the primary industries, i.e. agriculture, forestry and fishing. The volume (expressed in kg) of these inputs is, as far as energy and construction minerals is concerned determined via Statistics Denmark's energy statistics and raw material statistics. For biomass the principles from material flow accounting, MFA, (cf. Eurostat, 2001) are adopted.

Recycling

The product balances do not provide an exhaustive description of the recycling of residuals (such as paper, glass, iron) in the industries.[2] The extent of recycling in the industries is instead estimated from reports of, *inter alia*, the Danish Environmental Protection Agency. However, as a rule, recycling is only included in the present accounts to the extent that »inter-industry« recycling is involved, viz. production of recycling materials in one industry and the use in one or more industries different from the producer. For example, a large proportion of recycling in building and construction is not included, since it takes place internally in the industry. It is thus not the total recycling quantities, which are represented in this paper.

[2] The product balances are deficient in the case of the flows which are not connected with economic transactions and do not have a value. However, a significant proportion of recycling is included in the product balances e.g. imports and exports of waste products.

3 A physical input-output table for Denmark including waste flows

From the product balances a physical input-output table[3], cf. table 2, are constructed. It is an industry x industry table constructed from assumptions on the industries' market shares and production methods (industry-technology assumption).

In a physical input-output table the flows (in weight units) of materials between industries on one side and between industries and final demand (e.g. private consumption and exports) on the other are shown explicitly. Also, the flows of materials from abroad (imports) and natural resources extracted are shown in the tables.

Using a physical input-output tables as a frame for the accounting of physical flows ensures that the accounting is consistent, and that the material balances of industries and households are apparent.

2300 product balances

The physical input-output table shown in table 2 is based on 2 200 physical product balances, representing all products registered by the production statistics and foreign trade statistics by Statistics Denmark. Furthermore, inputs corresponding to the domestic extraction of biomass, fossil fuels and construction minerals have been included.

Presentation at aggregated level

The physical input-output table is in fact constructed at a 130 x 130 industry level, but since no effort has been done to verify the material balances at this detailed level it is only presented here at an 8-industry classification.

Input

In the lower part of table 2 the material balance is shown. The total input is 296.1 million tonnes. 140 million tonnes are input to *Agriculture, fishing and quarrying*, while 82 million tonnes are input to *Construction*.

Output and balance

On the output side those 296.1 million tonnes break down to 226 million tonnes of product output (row e.), 11.7 million tonnes of waste (row f.), 17.3 million tonnes of carbon and sulphur included in air emissions of CO_2 and SO_2 (row g.). A balance of 41 million tonnes is also present (row h.), corresponding to 14 per cent of the total output. This balance (which is calculated as a residual) can be explained by biomass waste and losses in agriculture, evaporation of water from products, air emissions other than carbon and sulphur. Furthermore, large amounts of dissipative uses of products like nutrients and minerals being spread on agricultural land are included. Chapter 4 explains how the individual non-product items within the balance are constructed.

Sludge

The negative item of 998 000 tonnes appearing as other output from *Public and personal services* is explained by the fact that this industry includes the sewage treatment plants which in the account has a large output of sludge, but no corressponding input of sewage water, etc. This negative item corresponds to an overestimation of other outputs for the other industries and households.

MFA and DMI

Table 3 shows the material balance of the Danish economy in a somewhat different format, in which the Economy Wide Material Flow (MFA) concept of Direct Material Input has been introduced[4]. In the upper part of this table the input side is specified. The total inputs are broken down by biomass extraction, extraction of construction minerals and domestic extraction of fossil fuels. If these items are added to the imports, the so-called direct material input, DMI, is obtained. In total, the direct material input was 176.6 million tonnes. In contrast to most MFA presentations, table 3 shows the industrial breakdown of DMI.

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[3] Physical input-output tables are described in Gravgård Pedersen (1999) and SEEA 2003, chp. 3

[4] MFA and DMI etc. are described in Eurostat (2001 and 2002). See also Gravgård Pedersen (2002).

When the inputs of domestic products and the inputs of recycling materials are added to the DMI, the total input of the economy as described in the physical input-output table is obtained. Thus, the last column in the upper part of table 3 corresponds to the input as shown in row d. in the physical input-output table, table 2.

DMI and waste

The DMI – as an indicator of the total inflow to the economy - can be compared with the flows of residuals from the economy presented in the bottom part of the table: solid waste of 11.7 million tonnes, Carbon and sulphur to air of 17.3 million tonnes and other wastes of 41.2 million tonnes. All together, the output of residuals was close to 70 million tonnes.

The difference of 107 million tonnes between the DMI at 177 million tonnes and the residuals of 70 million tonnes corresponds to the sum of accumulation in the economy and exports of products.

Table 2. Preliminary physical input-output table for all materials. Denmark 1999

	Intermediate input to industries									Final demand							Total product output
1000 Tonnes	1	2	3	4	5	6	7	8	Total	PC	GC	GFCF	S	X	SV	Total	
1 Agriculture, fishing and quarrying	3 862	17 211	6 572	75 213	63	1	3	50	**102 975**	672	-	3	6	13 798	- 18	**14 462**	**117 437**
2 Manufacturing	688	3 693	263	4 794	493	208	251	218	**10 607**	2 997	3	1 464	66	13 152	-1 452	**16 230**	**26 837**
3 Electricity, gas and water supply	97	638	3 766	3	193	22	78	253	**5 049**	832	-	-	- 141	0	-	**690**	**5 740**
4 Construction	-	-	-	-	-	-	-	-	**-**	-	-	75 923	-	-	-	**75 923**	**75 923**
5 Wholesale and retail trade, hotels, restaurants	-	-	-	-	-	-	-	-	**-**	-	-	- 3	-	3	-	**-**	**-**
6 Transport, storage and communication	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	**-**	**-**
7 Financial intermediation, business activities	-	0	-	-	-	-	-	-	**0**	0	-	0	- 0	0	-	**0**	**0**
8 Public and personal services	-	0	-	-	-	-	-	-	**0**	0	-	2	0	0	-	**2**	**2**
a. Input of Danish production	**4 647**	**21 542**	**10 601**	**80 010**	**749**	**231**	**332**	**521**	**118 632**	**4 500**	**3**	**77 389**	**- 68**	**26 953**	**-1 469**	**107 307**	**225 939**
1 Agriculture, fishing and quarrying	776	6 897	8 689	742	87	2	2	50	**17 245**	566	-	1	- 935	2 627	- 590	**1 668**	**18 913**
2 Manufacturing	3 494	10 387	352	1 676	738	1 714	150	387	**18 898**	3 852	10	- 781	- 178	6 988	-2 544	**7 347**	**26 245**
3 Electricity, gas and water supply	1	57	0	0	0	0	0	0	**58**	1	-	-	- 33	-	-	**- 32**	**26**
4 Construction	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	**-**	**-**
5 Wholesale and retail trade, hotels, restaurants	-	11	-	0	-	-	-	-	**11**	-	-	-	- 0	10	- 7	**3**	**15**
6 Transport, storage and communication	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	**-**	**-**
7 Financial intermediation, business activities	-	1	-	0	-	-	-	-	**1**	0	-	0	- 0	1	-	**1**	**2**
8 Public and personal services	-	0	-	-	0	-	-	-	**0**	1	-	0	0	0	- 0	**1**	**1**
b. Input of imports	**4 271**	**17 353**	**9 041**	**2 418**	**825**	**1 716**	**152**	**437**	**36 214**	**4 420**	**10**	**- 781**	**-1 146**	**9 626**	**-3 141**	**8 988**	**45 201**
c 1. Biomass extraction	**32 000**		**-**	**-**	**-**	**-**	**-**	**-**	**32 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**32 000**
c 2. Construction minerals	**78 572**		**-**	**-**	**-**	**-**	**-**	**-**	**78 572**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**78 572**
c 3. Fossil fuels	**20 847**		**-**	**-**	**-**	**-**	**-**	**-**	**20 847**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**20 847**
c.4. Recycling, etc.		**878**							**878**								**878**
d. Total input (a. + b. + c.)	**140 337**	**39 773**	**19 642**	**82 428**	**1 573**	**1 947**	**484**	**958**	**287 143**	**8 920**	**13**	**76 608**	**-1 215**	**36 579**	**-4 610**	**116 295**	**403 438**

Material balance	1	2	3	4	5	6	7	8	Total	PC	GC	Total
d'. Total input	**140 337**	**39 773**	**19 642**	**82 428**	**1 573**	**1 947**	**484**	**958**	**287 143**	**8 920**	**13**	**296 075**
e. Total product output	117 437	26 837	5 740	75 923	-	-	0	2	**225 939**	-	-	**225 939**
f. Solid waste	47	2 110	1 310	3 064	673	140	298	1 653	**9 294**	2 402	4	**11 701**
g. Carbon and Sulphur from air emissions	1 289	2 057	8 256	309	384	1 464	115	301	**14 174**	3 108	-	**17 283**
h. Other output	21 565	8 769	4 336	3 132	517	343	71	- 998	**37 735**	3 409	9	**41 153**
i. Total output (=e.+f.+g.+h.)	**140 337**	**39 773**	**19 642**	**82 428**	**1 573**	**1 947**	**484**	**958**	**287 143**	**8 920**	**13**	**296 075**

PC Private consumption
GC Public consumption
GFCF Gross fixed capital formation
S Stocks
X Exports
SV Special Volume item

Table 3. Overall material balance, including DMI - Denmark 1999

		Input							
		Biomass extraction	Extraction of construction minerals	Extraction of fossil fuels	Imports	DMI, Direct Material input	Danish products	Recycling	Total input
		1000 tonnes							
1	Agriculture, fishing and quarrying	32 000	78 572	20 847	4 271	**135 691**	4 647		**140 337**
2	Manufacturing	0	0	0	17 353	**17 353**	21 542	878	**39 773**
3	Electricity, gas and water supply	0	0	0	9 041	**9 041**	10 601		**19 642**
4	Construction	0	0	0	2 418	**2 418**	80 010		**82 428**
5	Wholesale and retail trade, hotels, restaurants	0	0	0	825	**825**	749		**1 573**
6	Transport, storage and communication	0	0	0	1 716	**1 716**	231		**1 947**
7	Financial intermediation, business activities	0	0	0	152	**152**	332		**484**
8	Public and personal services	0	0	0	437	**437**	521		**958**
	Total industries	**32 000**	**78 572**	**20 847**	**36 214**	**167 633**	**118 632**	**878**	**287 143**
	Private consumption	**0**	**0**	**0**	**4 420**	**4 420**	**4 500**		**8 920**
	Government consumption	**0**	**0**	**0**	**10**	**10**	**3**		**13**
	Exports	**0**	**0**	**0**	**9 626**	**9 626**	**26 953**		**36 579**
	Accumulation, etc.	**0**	**0**	**0**	**-5 068**	**-5 068**	**75 852**		**70 783**
	Total	**32 000**	**78 572**	**20 847**	**45 202**	**176 621**	**225 939**	**878**	**403 438**

		Output				
		Products	Solid waste	Carbon and sulphur from air emissions	Others	Total output (= total input)
		1000 tonnes				
1	Agriculture, fishing and quarrying	117 437	47	1 289	21 565	**140 337**
2	Manufacturing	26 837	2 110	2 057	8 769	**39 773**
3	Electricity, gas and water supply	5 740	1 310	8 256	4 336	**19 642**
4	Construction	75 923	3 064	309	3 132	**82 428**
5	Wholesale and retail trade, hotels, restaurants	0	673	384	517	**1 573**
6	Transport, storage and communication	0	140	1 464	343	**1 947**
7	Financial intermediation, business activities	0	298	115	71	**484**
8	Public and personal services	2	1 653	301	-998	**958**
	Total industries	**225 939**	**9 294**	**14 174**	**37 735**	**287 143**
	Private consumption	**0**	**2 402**	**3 108**	**3 409**	**8 920**
	Government consumption	**0**	**4**	**0**	**9**	**13**
	Exports	**36 579**	**-**	**0**		**36 579**
	Accumulation (GFCF, S, SV)	**70 783**	**-**	**0**		**70 783**
	Total	**342 301**	**11 701**	**17 283**	**41 153**	**403 438**

4 Waste account by type of waste and economic activities

Complete waste accounts for industries and households

This chapter summarises how the information on industries' and households' material surpluses by waste fractions are obtained, balanced and supplemented with information of the traditional waste statistics. The overall result was presented in the previous chapter as part of the physical input-output table and the overall balance for the economy.

In this chapter a national accounts classification by 26 industries is used[5],

The first step towards the construction of the waste accounts by industries and households is to establish physical balances (and physical input-ouput tables) for different groups of products. 9 groups of products were identified among the total set of product balances of the national accounts:

- Paper, etc. (70 product balances)
- Glass (50 product balances)
- Plastic (80 product balances)
- Food (animal and vegetable products) (300 product balances)
- Iron and metal products (450 product balances)
- Rubber (34 product balances)
- Wood products (25 product balances)
- Lubricating oil (1 product balance)
- Miscellaneous products (650 product balances)

These groups have been chosen because they are, to a large extent, well defined and correspond to important waste fractions in the Danish waste statistics. Therefore, it is possible directly to relate the material balances for these groups to the waste statistics and waste accounts.

For each of these groups material balances (and physical input-output tables) was constructed following the principles described in the previous chapters. Thus, for each product group, each industry and for the households it was assumed that the balance between the inputs on one side and the outputs of products on the other side could be used as an indicator of the actual amounts of the corresponding waste fraction generated. In generating these balances for only sub-sets of the product balances one has, however to be aware that mixed materials on either the output or the input side might create difficulties.

Mixed materials (output)

This is the case, for example, for many of the household appliances, which are included the physical input-output table for iron and metal products. The products are included if iron and metal is judged to make up the greater part of the weight. However, in most cases other materials like plastic and wood will also be part of the product. This means that the material composition might be somewhat diverse, even though the main part can be assumed to be iron and metal.

Mixed materials on the output side also mean that there will be a tendency for the physical balances to overestimate the material surplus of the industries because some of the material inputs might be used for production of products, which the balance in question does not take account of.

Mixed materials (input)

It should also be observed that the production of products relies on inputs of raw materials. Thus, in some cases an adjustment item had to be included as part of the

[5] As for the physical input-output table (table 2) the waste accounts have been calculated at an 130-industries classification, but since data has not been balanced and validated at this detail only the more aggregated data is presented here.

balance estimation. For wood products for example, the weight of timber etc. used for the production of wood products was included as inputs.

Io-based estimates

Table 4 present the results of the io-based material balance calculations for the product groups together with the corresponding amounts of waste as registered in the Danish waste statistics. The table also shows (aggregated) remaining groups of waste fractions in order present the total amount of waste as registered by the Danish waste statistics.

In total, the material balances for the nine groups "explains" 3.3 million tonnes or 28 per cent out of a total of Danish waste at 11.7 million tonnes. Some of the remaining waste could be included if the remaining product balances were included (the nine product groups represent 1660 products balances out of 2200 physical balances). However, a large discrepancy between a product-based estimation of the waste and the directly registered should be expected, since the waste statistics include waste from demolition of buildings, garden waste, and waste from energy production (fly ash, etc.), which cannot easily be related to the product input.

For each of the 9 product groups/waste fractions, the IO-based material balance estimates are larger than the amounts registered by the waste statistics. This is not surprising, since in the waste statistics quite large amounts of the specific materials will be included in e.g. the waste fraction category "suitable for incineration". All in all, the magnitudes of the IO-based estimates seem quite reasonable when compared to the waste statistics. . In other words, for these waste fractions it seems reasonable to substitute the information from the waste statistics for the IO-based estimates when it comes to constructing waste accounts by industries and households.

Table 4. Comparison of the IO-based material surplus estimates and corresponding direct information from waste statistics

	IO-based Material surplus estimate	Registered in Waste Statistics
	1000 tonnes	
Paper and cardboard	1 363	593
Glass	424	122
Plastic	686	38
Food products	631	218
Iron and metal products	544	441
Rubber	110	27
Wood products	347	27
Lubricating oil	39	60
Miscellanous products	477	n.a.
Suitable for incineration	n.a	3057
Other waste from construction	n.a	546
Others	n.a.	6 571
Total	**3 258**	**11 700**

Misallocation

While the overall estimation of the material surpluses, as shown in table 4, is probably sound enough, it must be realized that the allocation by industries and households (cf. table 6) in some cases and for some materials are wrong, since the estimation method excludes certain types of material flows. For instance, a lot of printed advertising material like circulars, handouts, fliers and brochures and free newspaper are handed out by industries to e.g. households for free, but these flows are not recorded by the economic statistics and the national accounts. The result is that the materials are accounted for as material surplus at the industries, but in reality they end up as waste from households.

The same kind of misallocation applies to packing materials accounted for in the industries using the materials for packing of products, which are delivered to other industries, exports or households.

Food products

For food products the initial estimation of material surpluses were not used directly as an indicator for the amounts of solid waste. Actually, large parts of the material surpluses of food waste end up as evaporation of water, etc. or end up in the sewer system. Thus, for the waste accounts a percentage had to be used for each of the industries and the households to indicate the amount ending up as solid waste. The material surplus indicated in table 4 is the result of this application of percentages to the initial estimation of material surplusses.

Distributed fractions

For specific waste statistics, fractions like *animal and vegetable fat* (cleansing agents, etc.); *organic compounds with and without halogens; inorganic compounds; other hazardous waste; Oil and chemical waste; and sludge* a basis for the distribution of the volumes of waste by industries and households has been constructed by calculating material surpluses for corresponding products. Thus, for organic chemicals, material balances, for instance, were calculated based on products balances for organic chemicals. However, the IO-based material surplus estimations were not used directly, since many of the chemicals never end up as solid waste. Instead, the distribution was taken as representative for the total waste generation registered by the waste statistics. When the waste was distributed in this way, care was taken to respect known waste totals for main sectors (households, construction, manufacturing, institutions, etc.) as given by the waste statistics. For the other fractions a similar approach was applied. For sludge the basis of distribution was the balance for food products.

Direct allocation of fractions

Waste fractions representing first of all construction waste (concrete, bricks, etc.) have been allocated to the *Construction* industry and *Households*, even though small amounts of waste are allocated to other industries as well according to the waste statistics. This reallocation is in line with the national accounting principle, which defines the construction industry from a functional approach, and, thus, collects all construction activities in one industry only.

For the fraction *Garden waste* the waste statistics' information on production in *Households* and *Construction* was used directly, while the small production of garden waste from industries and institutions was disregarded.

Adjustment to total waste

After the initial allocation of waste according to the procedure described above, 555 000 tonnes of waste were "missing" compared to the total of 11.7 million tonnes registered by the waste statistics. It corresponds to 5 per cent of the total – or in other words that 95 per cent of the registered waste flows were taken care of and allocated to industries and households by the accounting method used. In order to reach the total, the amount of waste from *Households* due to miscellaneous products was adjusted. The adjustment item was put on *Households*, since the initial amount of waste from *Households* seemed quite low compared to the amount of waste registered by the Danish waste statistics.

Emissions to air

To supplement the waste accounts the amounts of carbon and sulphur from air emissions by industries and households were estimated based on (NAMEA) accounts for the CO_2 and SO_2 emission. Since carbon and sulphur – at least in the Danish case – represent very substantial amounts of non-product output from the economy, it seems important to include these emissions explicitly in the overall material accounts and physical input-ouput tables as done in tables 2 and 3. Actually, the amounts of carbon and sulphur are larger than the amounts of solid waste.

Complete waste accounts by industries and households

Table 5 shows the result of the estimations. The total Danish amount of waste generation at 11.7 million tonnes are allocated by 19 waste fractions and 26 industries and households. As described, the information for 9 of the waste fractions are taken directly from the IO-based material surplus estimations. Some of the other fractions are allocated by industries by using IO-based material surpluses for characteristic product groups as keys for the allocation, while other fractions have been allocated directly to specific industries or the households based on the information given in the waste statistics.

Fractions

The waste accounts in table 5 give a detailed picture of the types of waste in the sense that the large amounts of waste registered at the waste statistics as *Waste suitable for incineration* or as *Waste not suitable for incineration* have been allocated to specific fractions. Furthermore, the category *non-specified* waste from the waste statistics has been replaced by specific sources in the waste accounts.

The waste accounts show that construction waste is the most significant when it comes to the weight. 2 800 000 tonnes or close to one quarter of the total amount of waste is characterised as construction waste.

After slag from energy production and sludge from sewage plants, paper was the dominant waste fraction, 1 362 000 tonnes.

The waste account shows that paper, glass, plastic, wood and rubber are more dominant fractions than what is immediately revealed by the waste statistics.

Industries and households

For households the Danish waste statistics registered 2 962 000 tonnes of waste. The waste account in table presents a number of 2 403 000 tonnes for *Households*. The smaller amount of waste is explained by the fact that the account does not allocate the waste from packing materials correctly. Thus, waste from packing of glass, paper, wood, plastic, metal etc. should be reallocated from the industries buying those products to the units actually discarding the packing waste. Also paper waste from fliers and free newspapers should be reallocated from the manufacturing and business industries to households.

For manufacturing, the Danish waste statistics registered 3 421 000 tonnes of waste. The corresponding number for the first 11 industries (code *109 - 4009*) in table 5 is at 3 467 000 tonnes. Due to misallocation of packing waste, etc. it could have been expected that the waste account would present a substantially higher number for manufacturing industries, etc. than the Danish waste statistics. This is not the case, and one reason can be that the Danish waste statistics use slightly different definitions of what constitute manufacturing and institutions, respectively, than those applied here. At least that could also explain why the waste account in table 5 presents 1 326 000 tonnes for institutions (here defined as the industries with codes *5000 – 8539*), while the waste statistics show a number of 995 000 tonnes.

Of the manufacturing industries especially *1509 manufacturing of food, beverages and tobacco* accounts for a large share of the waste generation. 7.3 per cent of the total is found here. However, this amount is probably somewhat overestimated due to the misallocation of packing materials.

Table 5. Solid waste by type and industries. Denmark 1999

			Paper	Glass	Plastic	Food wastes	Iron and metal	Rubber	Wood products	Miscellaneous products	Cleansing agents, detergents	Organic chemicals
			1000 tonnes									
1	109	Agriculture, horticulture and forestry	0.8	0.1	3.8	0.0	12.5	3.3	2.5	0.1	0.0	0.0
2	500	Fishing	0.1	0.0	1.5	0.0	0.2	0.0	0.0	1.8	0.0	0.0
3	1009	Mining and quarrying	4.1	0.0	5.7	1.4	1.2	0.1	2.4	0.0	0.0	0.0
4	1509	Mfr. of food, beverages and tobacco	70.8	166.0	51.8	184.6	45.2	0.8	8.3	0.9	0.1	4.3
5	1709	Mfr. of textiles, wearing apparel, leather	5.0	0.0	24.6	0.1	2.0	5.9	0.6	2.2	0.4	0.4
6	2009	Mfr. of wood products, printing and publ.	177.1	18.0	23.8	0.1	24.8	4.0	24.7	0.5	0.1	0.2
7	2309	Mfr. of chemicals, plastic products etc.	36.8	3.5	53.9	10.9	19.6	0.6	1.2	10.0	0.8	14.0
8	2600	Mfr. of other non-metallic mineral products	40.1	16.4	20.3	0.0	28.6	2.0	7.7	3.8	0.1	2.4
9	2709	Mfr. of basic metals and fabr. metal prod.	38.6	43.3	177.8	0.2	118.4	29.2	26.9	3.4	0.1	1.0
10	3600	Mfr. of furniture; manufacturing n.e.c.	23.3	15.3	45.0	0.6	15.5	0.8	34.5	6.1	0.0	0.1
11	4009	Electricity, gas and water supply	0.7	0.0	0.5	0.2	2.9	0.1	0.0	0.0	0.0	0.0
12	4500	Construction	5.8	82.1	77.8	0.2	2.7	0.3	21.8	22.6	0.0	0.3
13	5000	Sale and repair of motor vehicles etc.	14.1	3.2	11.4	0.1	29.7	54.9	5.9	3.0	0.0	0.8
14	5100	Ws. and commis. trade, exc. of m. vehicles	163.2	22.7	89.6	1.0	38.8	0.4	75.4	6.1	0.0	0.0
15	5200	Re. trade and repair work exc. of m. vehicles	35.6	0.9	14.4	0.3	16.8	0.4	3.3	3.9	0.0	0.0
16	5500	Hotels and restaurants	5.0	0.2	4.0	54.9	1.7	0.1	0.4	5.0	0.0	0.1
17	6009	Transport	16.5	2.5	8.6	0.4	13.1	0.9	18.9	11.1	0.0	0.0
18	6400	Post and telecommunications	46.6	0.0	0.5	0.0	6.5	0.1	1.7	2.3	0.0	0.0
19	6509	Financial intermediation and insurance etc.	34.1	0.0	1.4	0.3	1.8	0.1	0.0	1.3	0.0	0.0
20	7009	Real estate and renting activities	8.3	0.0	0.5	0.1	3.1	0.0	1.1	1.9	0.0	0.0
21	7209	Business activities etc.	201.2	0.2	2.9	0.7	17.5	0.5	4.3	14.7	0.0	0.5
22	7500	Public administration etc.	32.7	0.2	11.6	2.6	9.5	1.0	1.1	12.7	0.0	0.8
23	8000	Education	27.4	0.0	8.3	1.2	2.7	0.3	0.3	5.5	0.0	1.0
24	8519	Health care activities	14.1	0.8	5.3	2.1	1.3	1.1	0.0	8.9	0.0	1.0
25	8539	Social work activities	14.0	0.8	12.6	11.3	0.8	0.9	0.1	11.2	0.0	0.1
26	9009	Other community, social and personal act.	23.4	0.1	3.2	1.9	4.4	0.4	7.1	20.7	0.0	0.3
		Total industries	**1 039.2**	**376.3**	**660.8**	**275.2**	**421.4**	**108.0**	**250.2**	**159.5**	**2.0**	**27.3**
		Households	**323.6**	**48.2**	**24.9**	**355.5**	**122.1**	**2.4**	**95.6**	**871.0**	**0.1**	**7.5**
		Government consumption	**0.0**	**0.0**	**0.3**	**0.0**	**0.1**	**0.0**	**1.6**	**2.3**	**0.0**	**0.0**
		Total industries and consumption	**1 362.8**	**424.5**	**686.0**	**630.7**	**543.5**	**110.4**	**347.3**	**1 032.7**	**2.1**	**34.8**

			Inorganic chemicals	Lubricating oil	Other oil and chemical waste	Other hazardous waste, clinical waste, CFC's	Concrete, cement, bricks, asbestos and other construction waste	Slag, fly ash, sand	Sludge	Garden waste, soil	Total	Total
			1000 tonnes									Per cent
1	109	Agriculture, horticulture and forestry	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	25.5	0.2
2	500	Fishing	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.1
3	1009	Mining and quarrying	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.1
4	1509	Mfr. of food, beverages and tobacco	1.2	0.8	3.8	4.1	0.0	0.0	76.2	231.0	849.8	7.3
5	1709	Mfr. of textiles, wearing apparel, leather	0.2	0.1	0.4	0.4	0.0	0.0	0.0	0.0	42.1	0.4
6	2009	Mfr. of wood products, printing and publ.	0.7	0.2	1.0	0.2	0.0	0.0	0.0	0.0	275.5	2.4
7	2309	Mfr. of chemicals, plastic products etc.	12.1	1.3	6.1	13.4	0.0	0.0	4.5	0.0	188.7	1.6
8	2600	Mfr. of other non-metallic mineral products	1.9	0.6	2.9	2.3	0.0	0.0	0.0	0.0	129.4	1.1
9	2709	Mfr. of basic metals and fabr. metal prod.	1.6	2.7	12.6	0.9	0.0	25.6	0.1	0.0	482.5	4.1
10	3600	Mfr. of furniture; manufacturing n.e.c.	0.0	0.1	0.5	0.1	0.0	0.0	0.2	0.0	142.0	1.2
11	4009	Electricity, gas and water supply	0.0	0.2	0.7	0.0	0.0	1 299.0	5.3	0.0	1 309.6	11.2
12	4500	Construction	0.1	25.5	0.0	0.2	2 716.1	15.3	1.6	91.4	3 063.8	26.2
13	5000	Sale and repair of motor vehicles etc.	0.0	0.5	0.0	1.1	0.0	0.0	0.0	0.0	124.8	1.1
14	5100	Ws. and commis. trade, exc. of m. vehicles	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	398.7	3.4
15	5200	Re. trade and repair work exc. of m. vehicles	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	76.2	0.7
16	5500	Hotels and restaurants	0.0	0.1	0.0	0.1	0.0	0.0	1.5	0.0	73.0	0.6
17	6009	Transport	0.6	9.5	0.1	0.0	0.0	0.0	0.0	0.0	82.2	0.7
18	6400	Post and telecommunications	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	58.0	0.5
19	6509	Financial intermediation and insurance etc.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.9	0.3
20	7009	Real estate and renting activities	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	15.3	0.1
21	7209	Business activities etc.	0.2	0.5	0.0	0.7	0.0	0.0	0.0	0.0	243.8	2.1
22	7500	Public administration etc.	0.1	0.4	0.0	1.2	0.0	0.0	0.1	0.0	73.9	0.6
23	8000	Education	0.3	0.1	0.0	1.4	0.0	0.0	0.0	0.0	48.6	0.4
24	8519	Health care activities	0.3	0.1	0.0	5.3	0.0	0.0	0.1	0.0	40.4	0.3
25	8539	Social work activities	0.0	0.2	0.0	0.1	0.0	0.0	0.3	0.0	52.5	0.4
26	9009	Other community, social and personal act.	0.4	0.4	0.0	0.3	1.5	27.0	1.346.2	0.0	1.437.5	12.3
		Total industries	**20.0**	**51.2**	**28.0**	**31.9**	**2 717.7**	**1 366.9**	**1 436.2**	**322.4**	**9 294.2**	**79.4**
		Households	**0.5**	**8.9**	**0.1**	**4.6**	**82.5**	**0.0**	**0.2**	**454.8**	**2 402.5**	**20.5**
		Government consumption	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**4.2**	**0.0**
		Total industries and consumption	**20.5**	**60.1**	**28.1**	**36.5**	**2 800.2**	**1 367.0**	**1 436.4**	**777.2**	**11 700.8**	**100.0**

4009 Electricity, gas, and water supply accounts for 11.2 per cent of the total waste generation.

For *Construction* the waste accounts reproduce the information in the waste statistics quite closely (3 064 000 tonnes vs. 2 968 000 tonnes). 26.2 per cent of the waste generation is found here.

The amount of waste generated by 9009 Other community, social and personal activities comes mainly from the sewage plants.

5 Concluding remarks

Physical io-tables and material balances are useful

Combining the products balances of the national accounts with information on physical quantities from the foreign trade statistics, production statistics and various other statistics, it is possible to draw a rough picture of the material flows of the Danish economy. Physical input-output tables and material balances are useful tools for that purpose.

Material surplus used as indicators for waste for some materials

For certain product groups, it seems appropriate to relate the material surpluses, which can be estimated on the basis of the material balances to the waste statistics. Generally, this approach seems to give a good view of the actual composition of the waste, since large composite fractions like *waste suitable for incineration* can be broken down by more specific fractions (paper, wood, etc.).

Improved waste statistics on its way

The present Danish waste statistics include some information about sources for the waste generation, which to some extent can be related to the national accounts classification of industries etc. It is expected that the level of detail of the statistics with respect to the sources for waste generation will be improved in the future. However, some information will still be missing in relation to the construction of waste accounts as satellites to the national accounts. Thus, the material balance approach will also in the future be a useful approach to the construction of waste accounts, including a national accounts oriented breakdown of the waste generation.

Weak points of the material balance approach

For some types of waste, the material balance approach presented here has shown to be deficient in the sense that it results in a misallocation of the waste with respect to the sources of the waste. This is a problem especially in relation to the allocation of waste from packing materials. The industries buying the packing materials and not the industries and households, which discard the packing, are accounted for as the source of the packing waste. However, with some effort it will be possible to correct this misallocation.

Other subjects for improvements of the waste accounts presented here would include better accounting for the accumulation and scrapping of materials, e.g. by including data on life cycle of products into the accounting. A better representation of the recycling and treatment of waste would be useful as well.

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