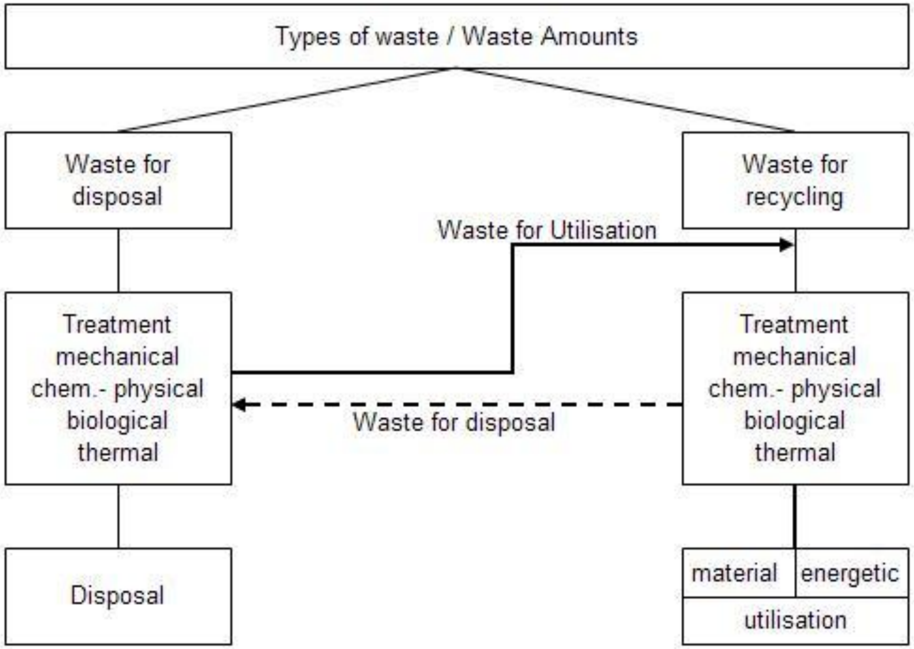
2. Types, Amounts and Composition of Waste

Terminology

- So far, there are no DINs or ENs on waste management terminology.
- For single definitions see the preambles to the Waste Law and Regulations and the Administrative Instructions as well as DIN 30706.
- All waste is allocated in a 6-digit decimal system to the Waste Key Numbers of the Waste Register Directive AVV according to type.
- In balances, the kinds of waste can mostly be subdivided into waste for utilisation (mat = materially and en = energetically) and waste for disposal (cf. Chapter 1) with the following „interconnections“:



European Waste Index List

Denomination of waste and classification of waste according to its treatment necessity.

Example

07	**WASTE FROM ORGANIC CHEMICAL PROCESSES**
07 01	Waste from production, dressing, trading and application of basic organic chemicals
07 01 03	organic halogenated solvents, scrubbing liquids and lye
17	**CONSTRUCTION AND BREAKING OFF WASTE** (including excavation of polluted locations)
17 01	Concrete, bricks, tiles and ceramics
17 01 01	Concrete
17 01 02	Bricks
17 01 03	Tiles, bricks, and ceramics
17 01 06	Mixtures of or separate factions of concrete, bricks, tiles and ceramics containing dangerous materials

European Waste Index List

20 MUNICIPAL WASTES AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES INCLUDING SEPARATELY COLLECTED FRACTIONS

20 01 Separately collected fractions

20 01 01	Paper and cardboard
20 01 02	Glass
20 01 03	Small plastics
20 01 04	Other plastics
20 01 05	Small metals (cans, etc.)
20 01 06	Other metals
20 01 07	Wood
20 01 08	Organic kitchen waste
20 01 10	Clothes
20 01 11	Textiles
20 01 13*	Solvents
20 01 14*	Acids
20 01 15*	Alkalines
20 01 17*	Photochemicals
20 01 19*	Pesticides
20 01 23*	Discarded equipment containing chlorofluorocarbons
20 01 25	Edible oil and fat
20 01 26*	Oil and fat other than those mentioned in 20 04 25

European Waste Index List

20 MUNICIPAL WASTES AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES INCLUDING SEPARATELY COLLECTED FRACTIONS

20 01 Separately collected fractions

20 01 27*	Paint, inks, adhesives and resins containing dangerous substances
20 01 28	Paint, inks, adhesives and resins other than those mentioned in 20 01 27
20 01 29*	Detergents containing dangerous substances
20 01 30	Detergents other than those mentioned in 20 01 29
20 01 31*	Cytotoxic and cytostatic medicines
20 01 32	Medicines other than those mentioned in 20 01 31
20 01 33*	Mixed batteries and accumulators containing batteries or accumulators included in 16 06 01, 16 06 02 or 16 06 03
20 01 34	Batteries and accumulators other than those mentioned in 20 01 33
20 01 35*	Discarded equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components
20 01 36	Discarded equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35

20 02 Garden and park wastes (including cemetery waste)

20 02 01	Compostable waste
20 02 02	Soil and stones
20 02 03	Other non-compostable wastes

20 03 Other municipal wastes

20 03 01	Mixed municipal waste
20 03 02	Waste from markets
20 03 03	Street cleaning residues
20 03 04	Septic tank sludge

Terminology / Waste Types

- No DIN for waste terms; Sources in AVV, VO, laws, statistics
- Subdivision/allocation recommended for MSW balances:

	Kinds of Waste	Definition + Explanation	Waste for	
	EWC No.		Disposal	Utilisation
1.1	**Domestic Waste DW** 20 03 31	Solid waste from private households, which are collected and transported in standardised containers which are prescribed in the respective disposal areas.	X	
1.2	**Commercial Waste CW** 20 03 31	Solid waste from shops, small industries and service companies which is removed together with DW through the municipal waste container removal.	X	
1	**Domestic and Commercial Waste DW + CW** 20 03 31	Sum of 1.1 + 1.2, corresponds to the amounts of the municipal waste container removal; Breakdown into in (1.1) and (1.2) generally possible only through separate removal of DW containers with weighing of DW + CW; ratio of the CW can be estimated via the container volume deployed in commerce.	X	
2	**Bulky Waste BW** 20 03 31	Solid waste cast off by statutory connected which because of its bulkiness does not fit into the prescribed containers and is collected separately from the DW through the municipal waste collections (regular removal or removal on demand).	X	X
3	**Small amounts from private deliveries SAPD** 20 03 31	Bulky waste which is delivered privately by households and small industries to civic amenity sites, local work yards, so-called special waste collection points, or directly to central disposal plants. If necessary, allocation to Group 2 (BW).	X	X
4	**Domestic waste-like commercial waste dwl CW (without BSW)** 20 03 31	Waste accrued in commercial building or commercial and industrial companies which is not production-specific, such as packing and office waste, which is removed separately from domestic waste: either utilised after sorting or disposed together with domestic waste.	X	X
5	**Sorting residues** SR No EWC No.	Waste for disposal from sorting plants (sorting residues), for instance DSG plants, composting plants, differentiated according to origin and waste type)	X	
6	**High caloric value waste SBS / BRAM** 20 01 / 20 03	Waste with high heating values which is collected separately or gained from sorting for energetic utilisation or thermal disposal	X	Xen
7	**GIP slags** 19 01 01	Slags from incineration	X	Xmat
8	**MBT output** 19 05 / 06	Output from the mechanical-biological treatment of waste for depositing	X	

Types of Municipal Waste

	Kinds of Waste EWC No.	Definition + Explanation	Waste for: Disposal	Waste for: Utilisation
9	**Street sweepings SW** 20 03 03	Waste from public street cleaning; partly, waste from public litter bins are subsumed here, too	X	Xmat
10	**Market Waste MW** 20 03 02	Waste from the operation and cleaning of markets, e.g. fruit and vegetable waste and packing materials. Can be balanced under GW, if necessary,	X	X
11	**Garden and Park Waste G&P** 20 02 01 und 20 02 03	Mainly herbal waste from the maintenance of public parks, gardens, grassed areas, cemeteries and roadside planting (compostable and non-compostable)	(X)	Xmat
12	**Recovered Paper RP** 20 01 01	Used paper, cardboard and carton (PCC) collected via publicly accessible collection systems; amounts which are collected directly through commercial collections should be balanced separately.		Xmat
13	**Recovered Glass RG** 20 01 02	Separately collected used glass (container glass, plate glass, etc.).		Xmat
14	**Scrap Metal/Scrap SM** 20 01 04	Separately collected scrap metal and scrap.		Xmat
15	**Lightweight packaging LWP** 20 01 03 / 05 / 06	Separately collected packing materials made of plastic, metal and composite materials.		X
16	**Used Textiles UT** 20 01 11	Separately collected used textiles for utilisation		Xmat
17	**Bio-/Green Waste** 20 01 08	Separately collected compost raw materials for utilisation		Xmat
18	**Scrap Wood** 20 01 07	Separately collected scrap wood for material or energetic utilisation, or for disposal in case of high pollution	X	X
19	**Problematic or hazardous waste in small amounts** 20 01 13to 36	Separately collected problematic waste and small amounts of hazardous waste from households, commerce and public institutions	X	X
20	**Electronic scrap without cooling appliances** 20 01 35*	Separately collected electric and electronic implements (white and brown goods, including small appliances)	X	X
21	**Cooling appliances** 20 01 23*	Separately collected cooling appliances	X	X
22	**Solid Municipal Waste SMW** 20	Sum of the solid waste from households and commerce without construction site waste and production specific waste for utilisation or disposal. Consider double counting of sorting residues and secondary waste.	X	X

Types of Municipal Waste

	Kinds of Waste	Definition + Explanation	Waste for	
	EWC No.		Disposal	Utilisation
23	**Rakings RG** 19 08 01	Waste from wastewater treatment, partly dewatered (state dewatering degree!). Only balanceable separately if the rakings are not removed in discharge systems in domestic waste collection tours.	X	Xmat
24	**Grit Chamber Trappings GCT** 19 08 02	Waste from wastewater treatment and sewage system and gully cleaning	X	Xmat
25	**Sewage Sludge SS** 19 08 04 und 05	Liquid, dewatered or dried sludge from the operation of municipal wastewater treatment plants (industrial sludge to be balanced separately under EAK No. **19 08 04**, not as municipal waste); state water contents!	X	Xmat
26	**Waste from Waterway Management** no EAK No.	Waste like floating refuse, flotsam, mowing and rakings	X	Xmat
27	**Other Municipal Waste** 2003	Hospital-specific waste and other municipal waste which cannot be allocated to one of the abovementioned groups.	**X**	
28	**Municipal Waste MW** no EAK No.	Sum of the solid, pasty or liquid municipal amounts of waste, excluding waste from building sites		
29	**Building Site Waste BSW** 17 02 01 Wood 17 02 03 Plastic 17 02 04* Wood with hazardous pollutions	Non-mineral building site waste, such as wood, textile or plastic floors, containers, packing material, renovation waste, roofing paper, etc.	X	X
30	**Building Rubble BR** 17 01 and 17 09	Mineral building site waste without excavation spoils	X	Xmat
31	**Excavation Spoils ES** 17 05 and 17 05 03*	Top soil, gravel, sand, loam, clay, turf, stones, rocks (17 05 03* if contaminated)	X	Xmat
32	**Roadway Rubble RR** 17 03 Blacktops	Waste from broken-up streets, such as gravel, compound substances such as asphalt or concrete rubble; paving stones and kerbstones	X	Xmat
33	**Building Rubble with hazardous contaminations** 17 09 01*to 17 09 03*.	Hazardously contaminated building rubble	X	
34	**Σ Building Site Waste**17	**Sum of the building waste types**		

Municipal Waste – Categories for Disposal

- The above-mentioned types of waste can be subsumed in the different categories:

  - Waste for material disposal
  - Waste for energetic utilisation

  - Waste for disposal through incineration
  - Waste for disposal after mechanical-biological treatment

  - Deposited waste for disposal
  - Waste to be disposed of
  - Waste for direct depositing

Waste Statutes

- Waste Statutes serve to
  - supply information and determination of waste disposal tasks through the local waste disposal contractors,
  - determine the duties of the waste producer, particularly sorting duties
  - supply information about admissible containers
  - publish the waste removal fees.

- Waste statues have a guiding impact on waste management

Waste Management Statutes in the Hanover Region

(Waste Statutes in the version dating from 17.12.2003)

I. Section: General Regulations

§ 1 Tasks, public disposal contractors

§ 2 Waste consulting, separation of utilisable waste

§ 3 Extent of waste disposal

§ 4 Connection and usage rights, connection and usage obligation

§ 5 Reporting, disclosure and toleration obligation

§ 6 Interruption of waste disposal

§ 7 Production of waste, property transfer

§ 8 Dumping grounds, civic amenity sites

II. Section: Disposal of Domestic Waste and Commercial Municipal Waste

§ 9 Terminology

§ 10 Permitted waste containers, removal procedure

§ 11 Location and transportation ways of waste containers

§ 12 Usage of the waste containers

§ 13 Usage and supply of refuse bags

§ 14 Removal times, cancellation of emptying

III. Section: Disposal of utilisable and other types of waste

§ 15 Recovered paper

§ 16 Recovered glass

§ 17 Waste which must be taken back by the producers

§ 18 Other utilisable types of waste

§ 19 Bulky waste

§ 20 Electronic appliances

§ 21 Construction site waste

§ 22 Compostable waste

§ 23 Problematic waste, small amounts of barred waste

§ 24 Oil and gasoline separator contents, residues from grit chambers and sludge traps

§ 25 Disposal evidence, declarations of acceptance

V. Section: Final Provisions

§ 26 Waste fees, remuneration

§ 27 Abuse of disposal implements

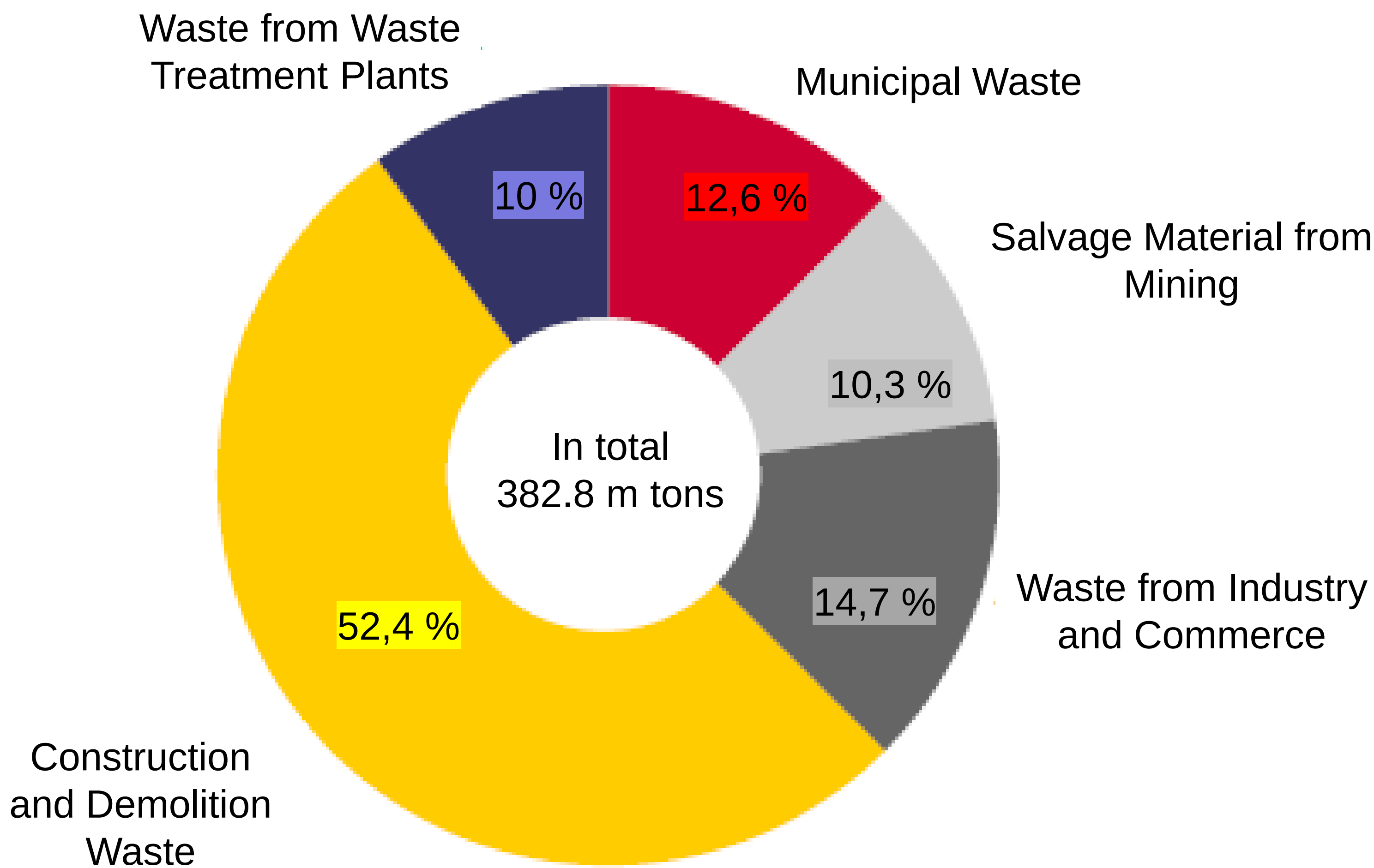
§ 28 Coercives

§ 29 Offences

§ 30 Coming into effect

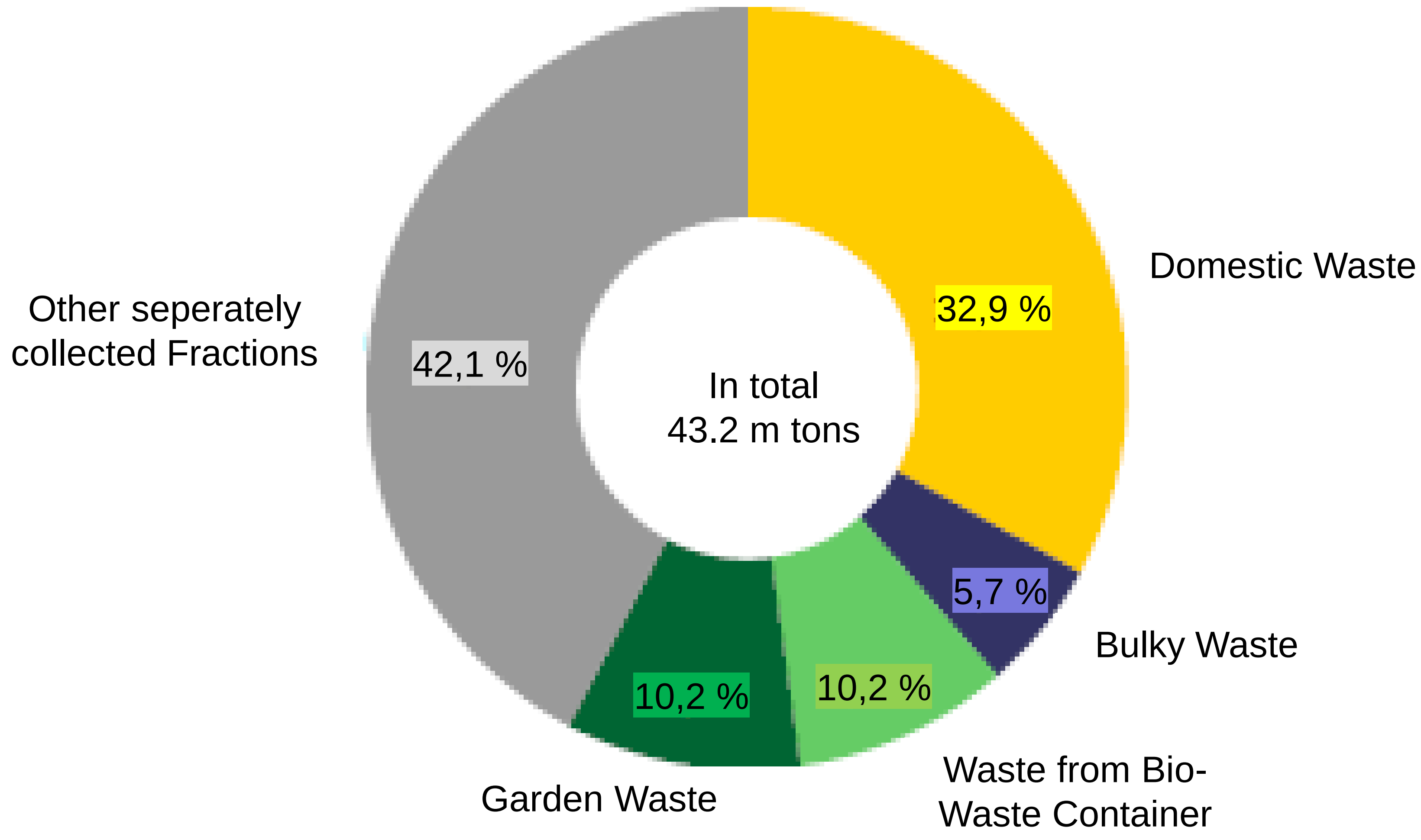
Composition of the entire waste amounts in 2008

Waste potential = waste for utilization + waste for elimination



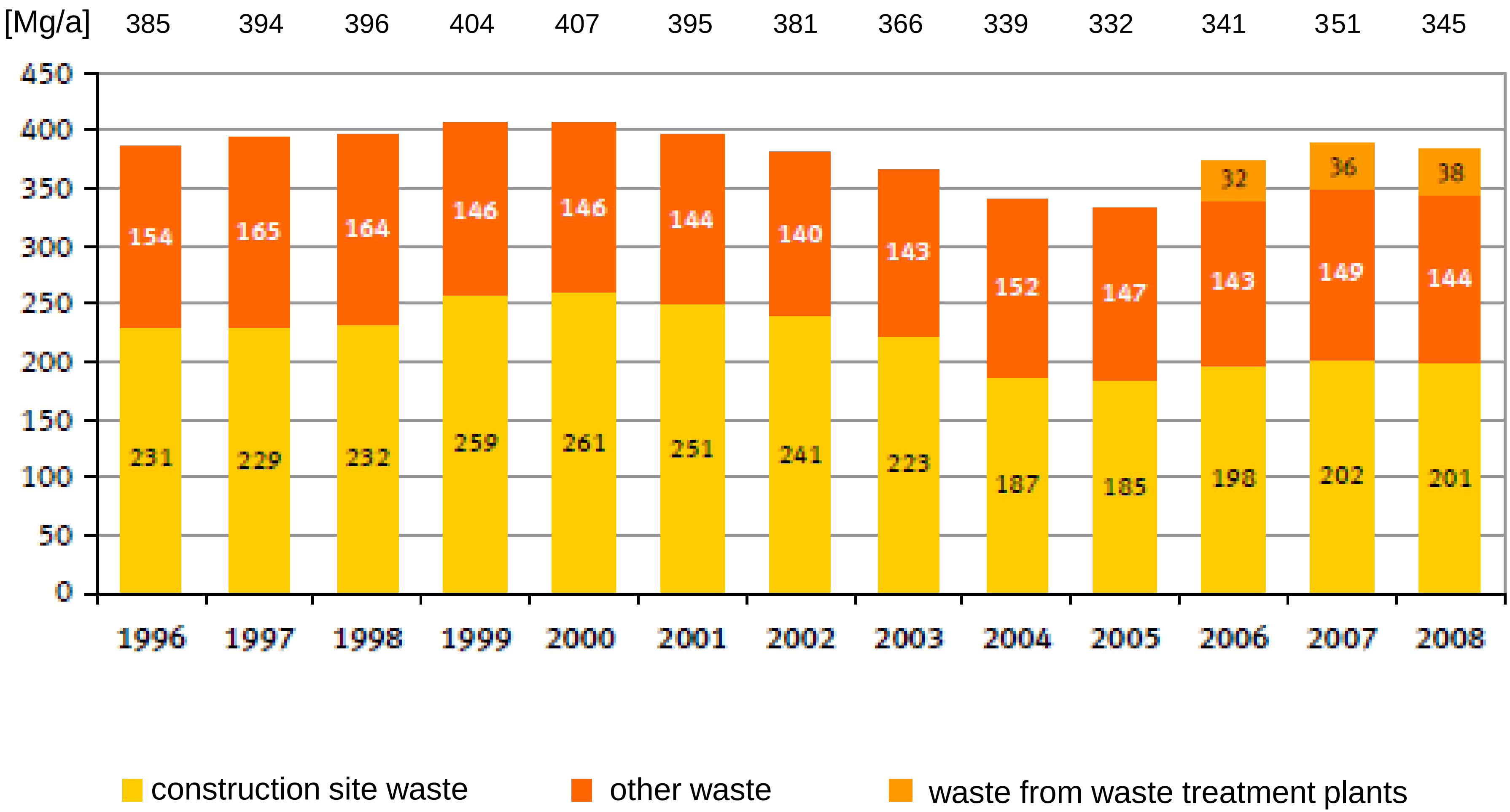
(Source: Federal Statistical Office. Report on the eco-economic resource accounts 2010)

Composition of the non-hazardous domestic waste in 2008



(Source: Federal Statistical Office. Report on the eco-economic resource accounts 2010)

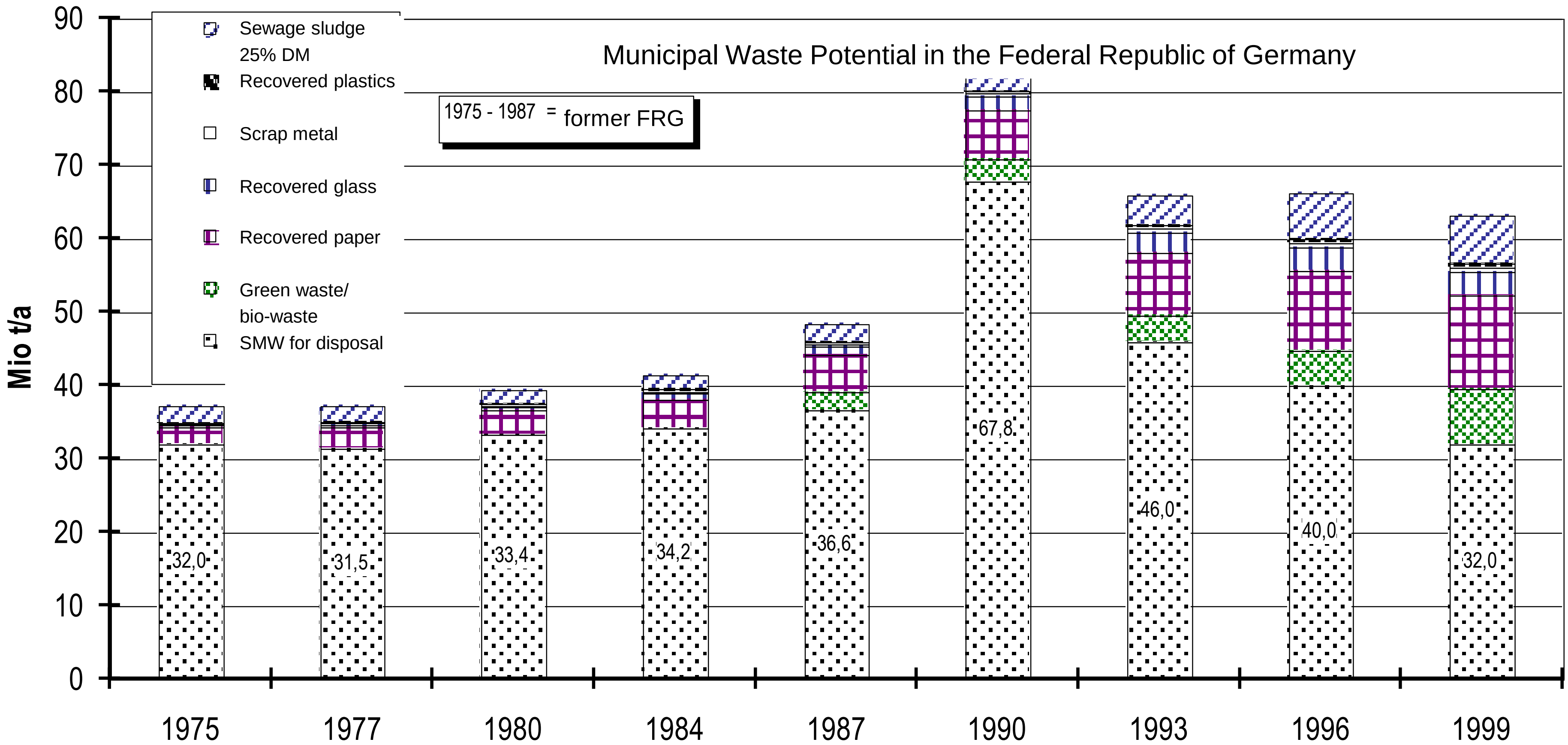
Development of Waste Amounts in Germany UGR2010



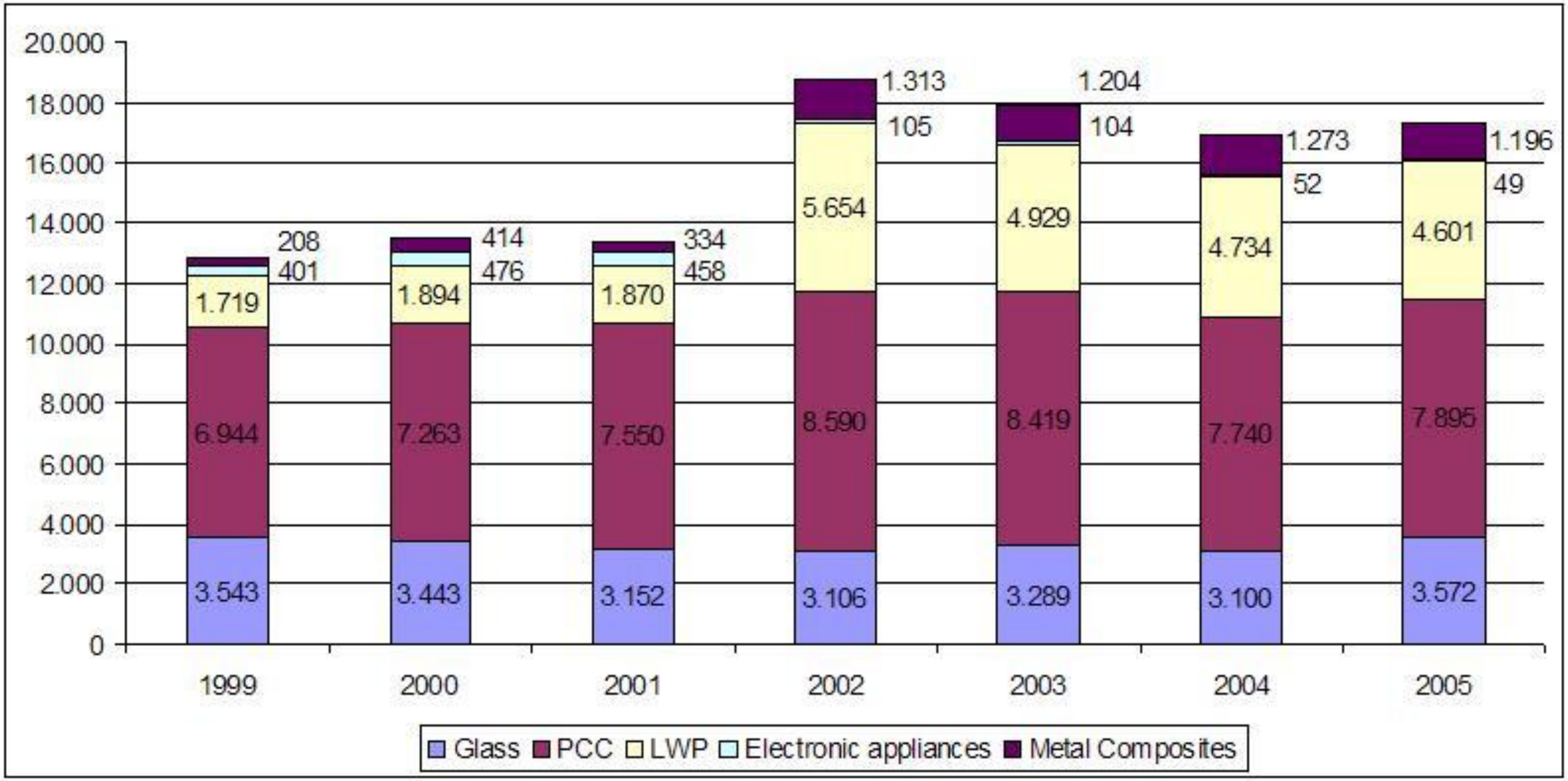
(Source: Federal Statistical Office. Report on the eco-economic resource accounts 2010)

Waste Amounts

- Waste Potential = Waste for Utilisation+ Waste for Disposal



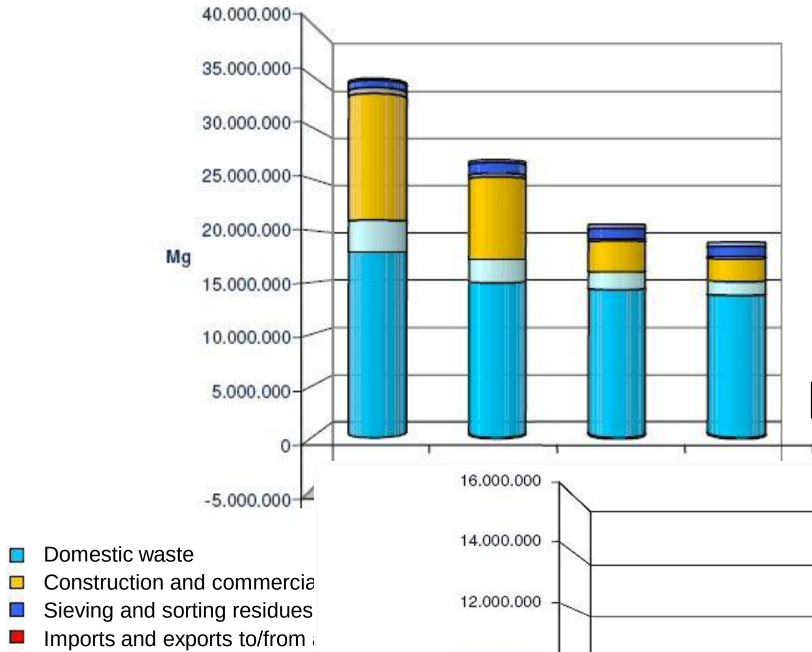
12.815 13.491 13.364 18.769 17.944 16.899 17.313



Total Waste Amounts in Germany

Waste which must be disposed

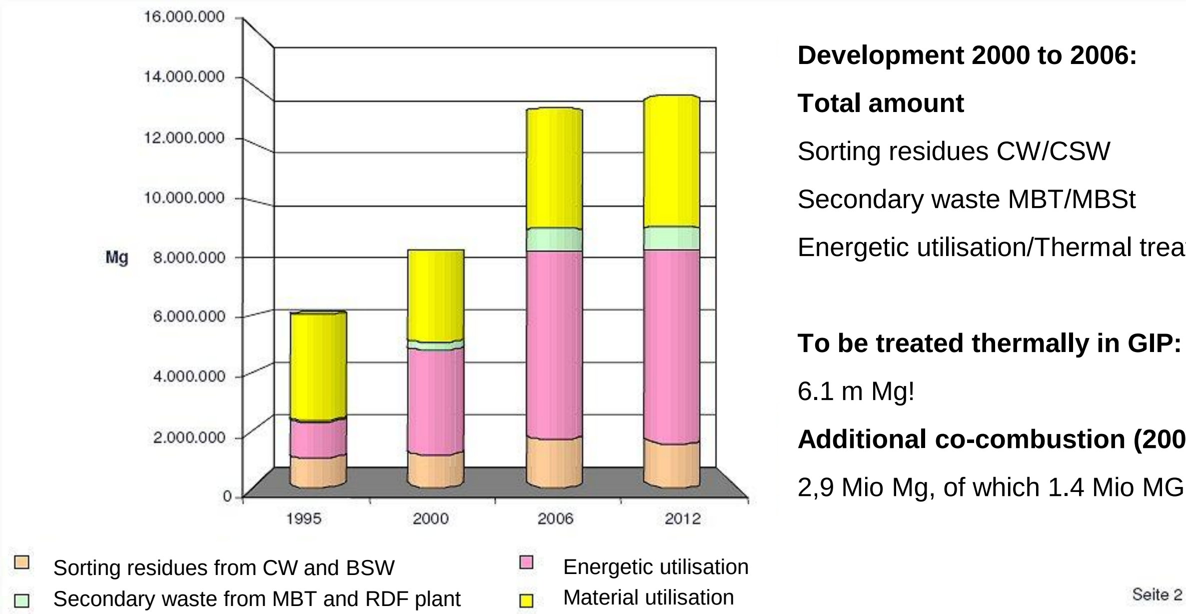
(Source: Beate Kummer, wte 2005, Prognos)



Development 2000 to 2006:

Total amount	**- 23 %**
Domestic Waste	- 4 %
Bulky Waste (e.g.)	- 24 %
Construction/Commercial waste	- 63 %
Sieving/Sorting residues	0 %

Freely tradeable commercial waste



Development 2000 to 2006:

Total amount	**+ 55 %**
Sorting residues CW/CSW	+ 48 %
Secondary waste MBT/MBSt	+ 195 %
Energetic utilisation/Thermal treatment	+ 78 %

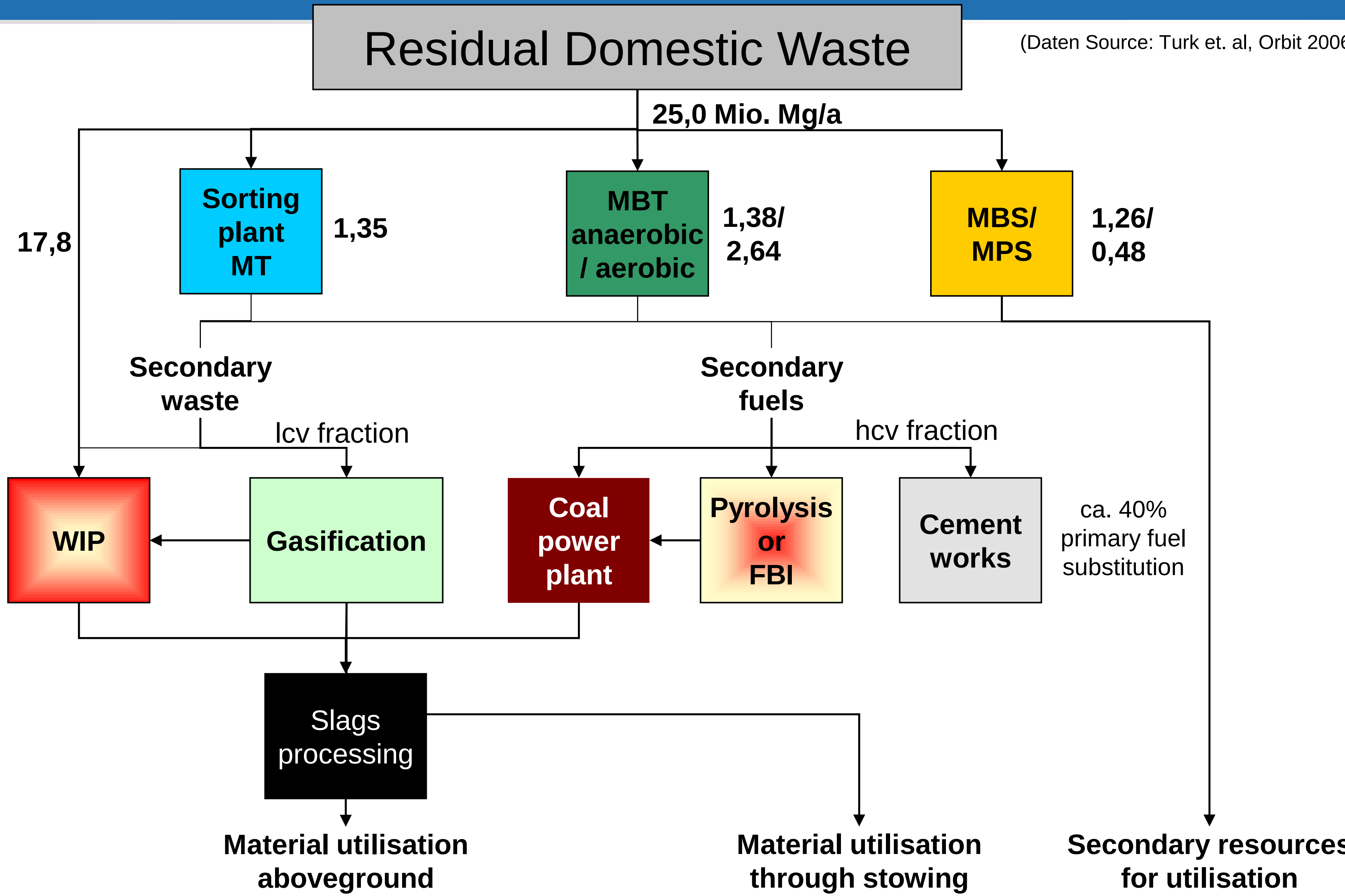
To be treated thermally in GIP:

6.1 m Mg!

Additional co-combustion (2006):

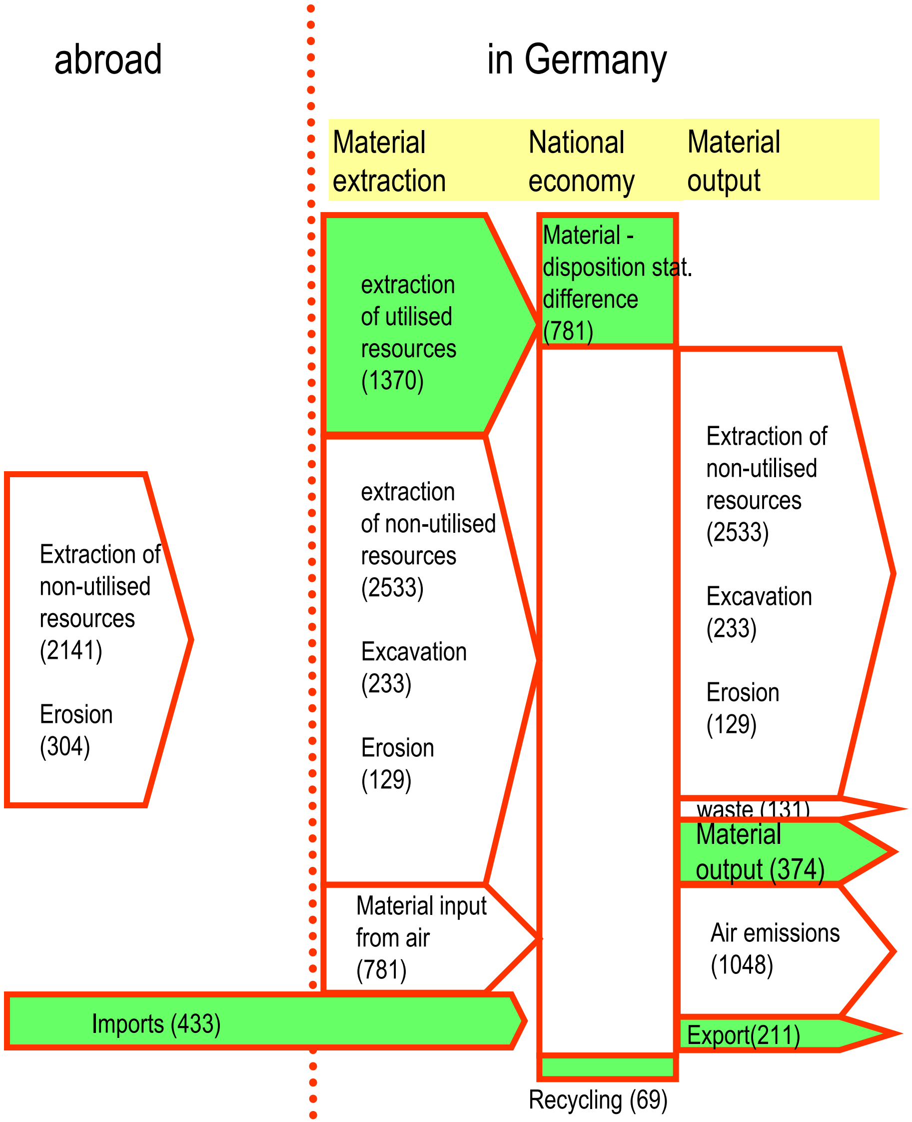
2,9 Mio Mg, of which 1.4 Mio MG from MBT/MBSt

Disposal Situation

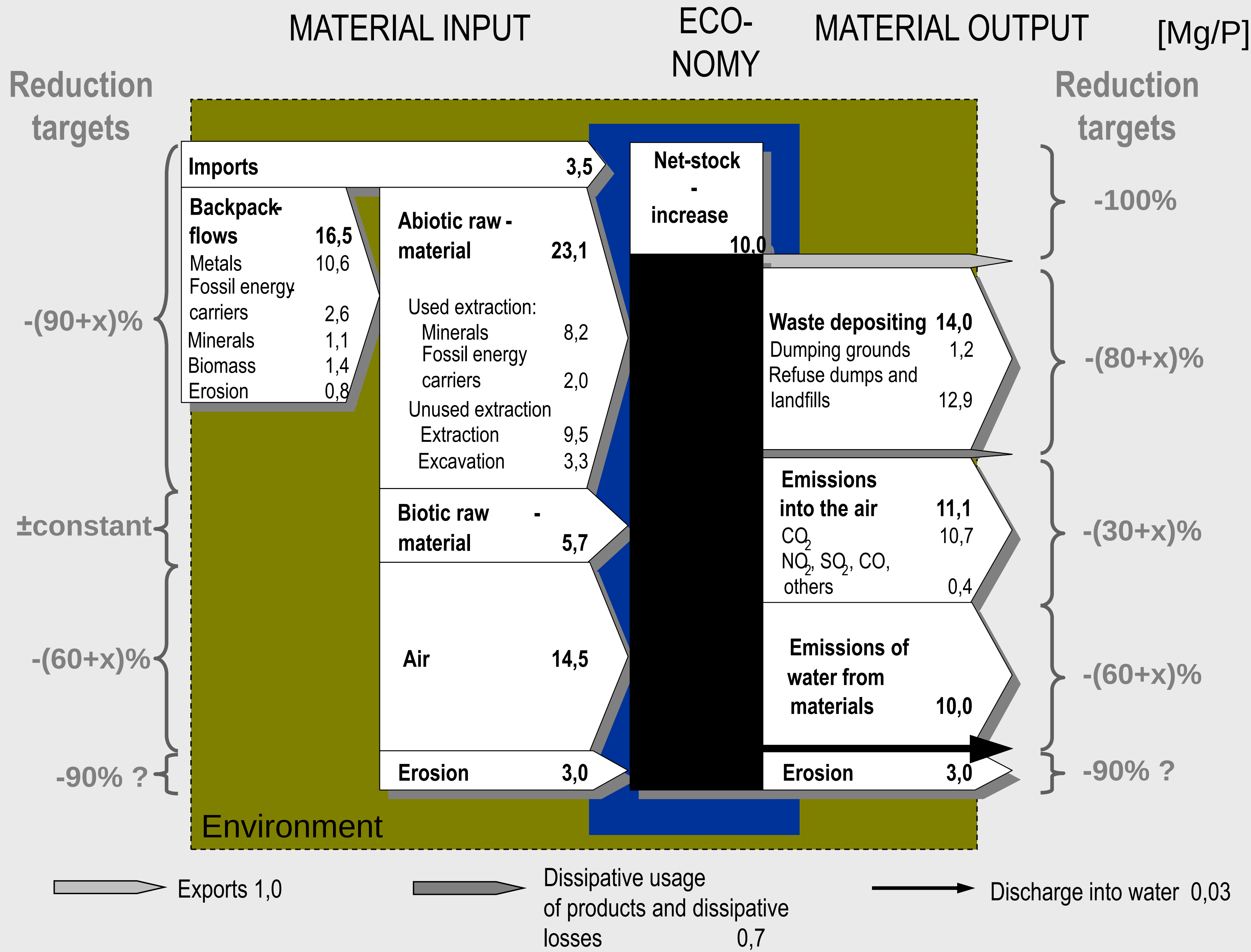


Example Material Flow Balance in Germany 1991

Source: Wuppertal Institute



- Should **water** 10-fold compared to all other substances and **air** be included in the balances?
- Non-utilised material flows > utilised ones
- Storage increase mainly from construction materials; waste + resources depot
- Recycling set too low with 69 Mio t/a. Excavations of 200 - 300 Mio t/a are in construction practice mainly used as filling material (utilisation)
- Municipal waste at 40-50 Mio t/a only <10 % of the mineral waste and < 1 % of the total material efforts

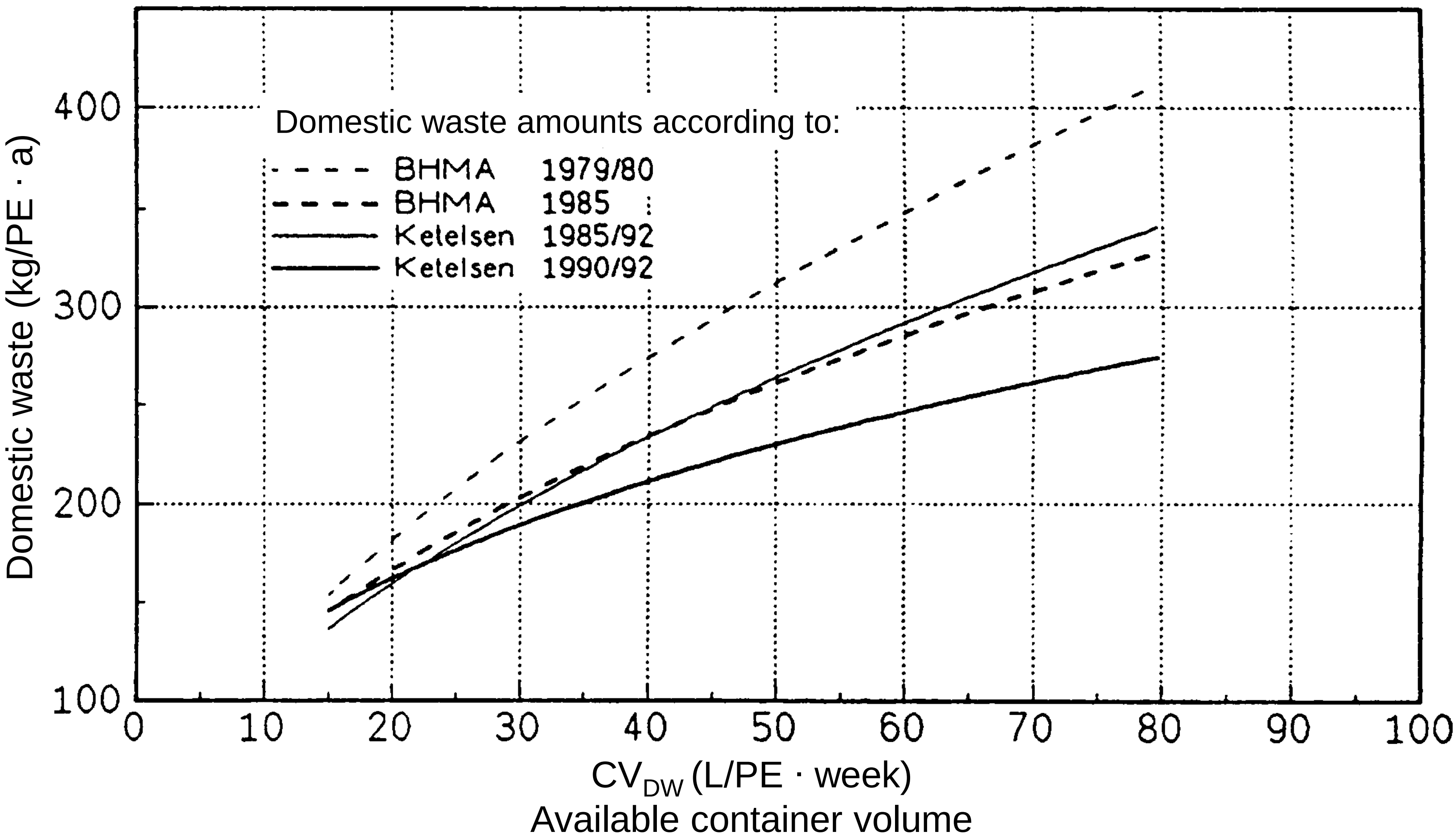


MATERIAL INPUT
ECO-NOMY
MATERIAL OUTPUT
[Mg/P]
Reduction targets
Reduction targets
Imports 3,5
Backpack-flows 16,5
Metals 10,6
Fossil energy carriers 2,6
Minerals 1,1
Biomass 1,4
Erosion 0,8
Abiotic raw - material 23,1
Used extraction:
Minerals 8,2
Fossil energy carriers 2,0
Unused extraction
Extraction 9,5
Excavation 3,3
Biotic raw - material 5,7
Air 14,5
Erosion 3,0
Net-stock - increase 10,0
Waste depositing 14,0
Dumping grounds 1,2
Refuse dumps and landfills 12,9
Emissions into the air 11,1
CO_2 10,7
NO_2, SO_2, CO, others 0,4
Emissions of water from materials 10,0
Erosion 3,0
-(90+x)%
±constant
-(60+x)%
-90% ?
-100%
-(80+x)%
-(30+x)%
-(60+x)%
-90% ?
Environment
Exports 1,0
Dissipative usage of products and dissipative losses 0,7
Discharge into water 0,03

Domestic Waste Amount

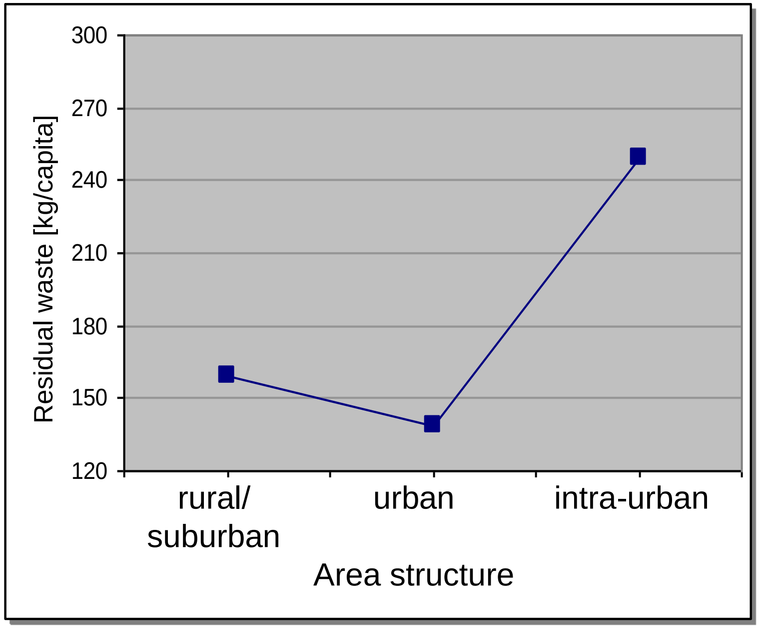
- The DW amounts are compositions are influenced by the following factors :
  - Kind of waste collection (container size and volume supply, removal frequency)
  - Settlement structure (building density, particularly garden waste; frequently used term: „AS"=area structure);
  - Extent and kind of available systems for material utilisation (separate collection)
  - Social structure, standard of living
  - Ratio of commercial waste collected with the domestic waste (impact of the statutes and the container sizes)
  - Range of goods, packaging, consumers and consumption habits
  - Seasonal influences
  - Overnight stays by non-residents
  - Incentives for utilisation and avoidance (for instance height of fees)
- DW Potential: ca. 300 to 250 kg/I*a; since 2000 utilisation > disposal
- Domestic Waste = ca. 70%-80 % private DW + 20%-30% commercial waste (CW)
- Bulky waste10-100 kg/I*a; for data on further types of waste, please see Script

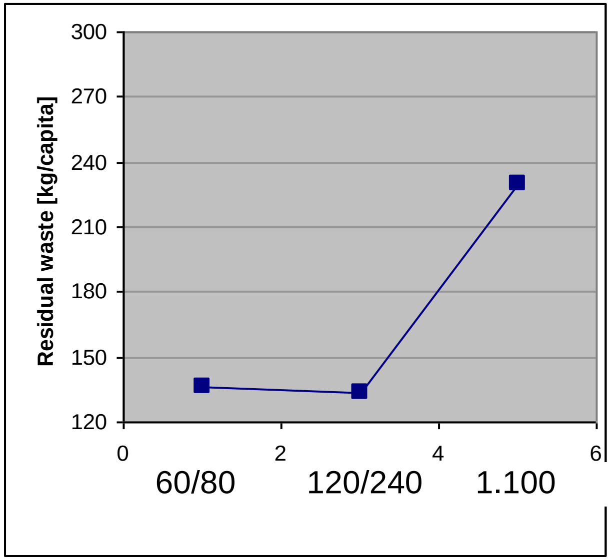
Domestic Waste Amounts= f (Container Volume Supply)

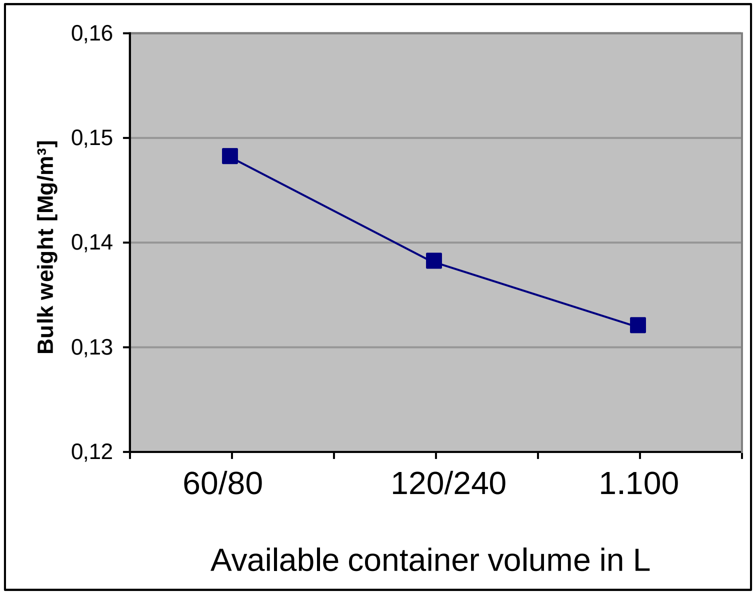


Influence on the Residual Waste Amounts

Bavarian Ministry of State for Environment, Health and Consumer Protection „Composition and Pollutant Contents of Domestic Waste "



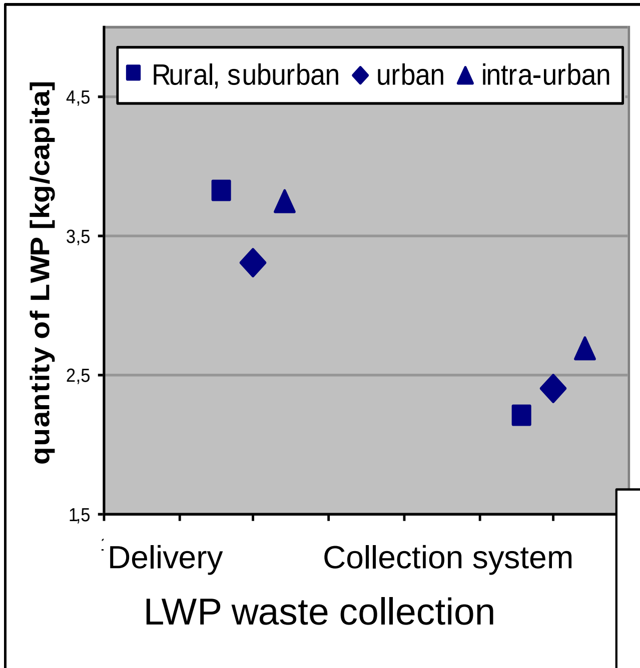


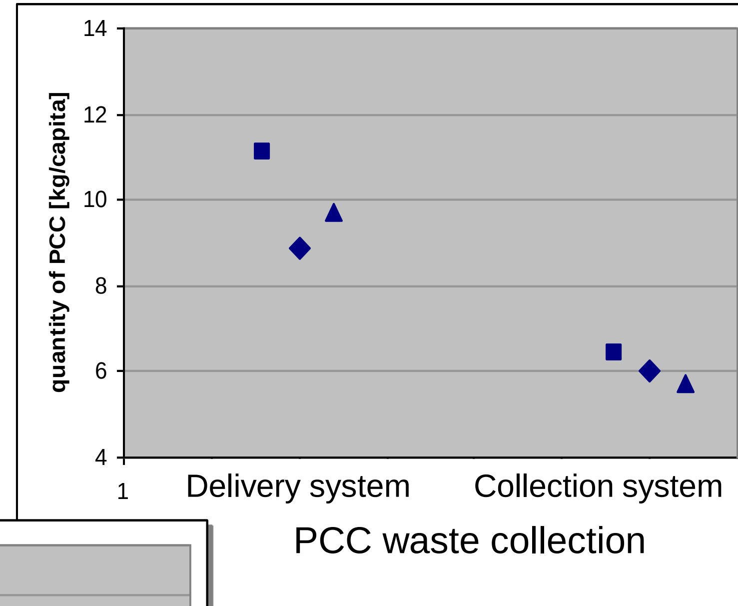


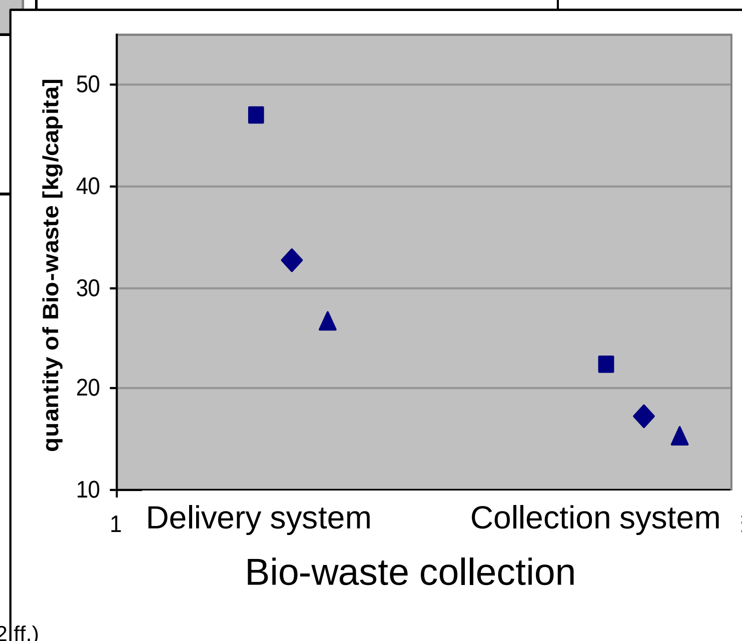
17 Residual waste sorting analyses
15 Bavarian Regional Authorities
20,000 Single values
769 sorted random samples

(according to Weigand , Marb: Müll und Abfall 10 (2005) 522 ff.)

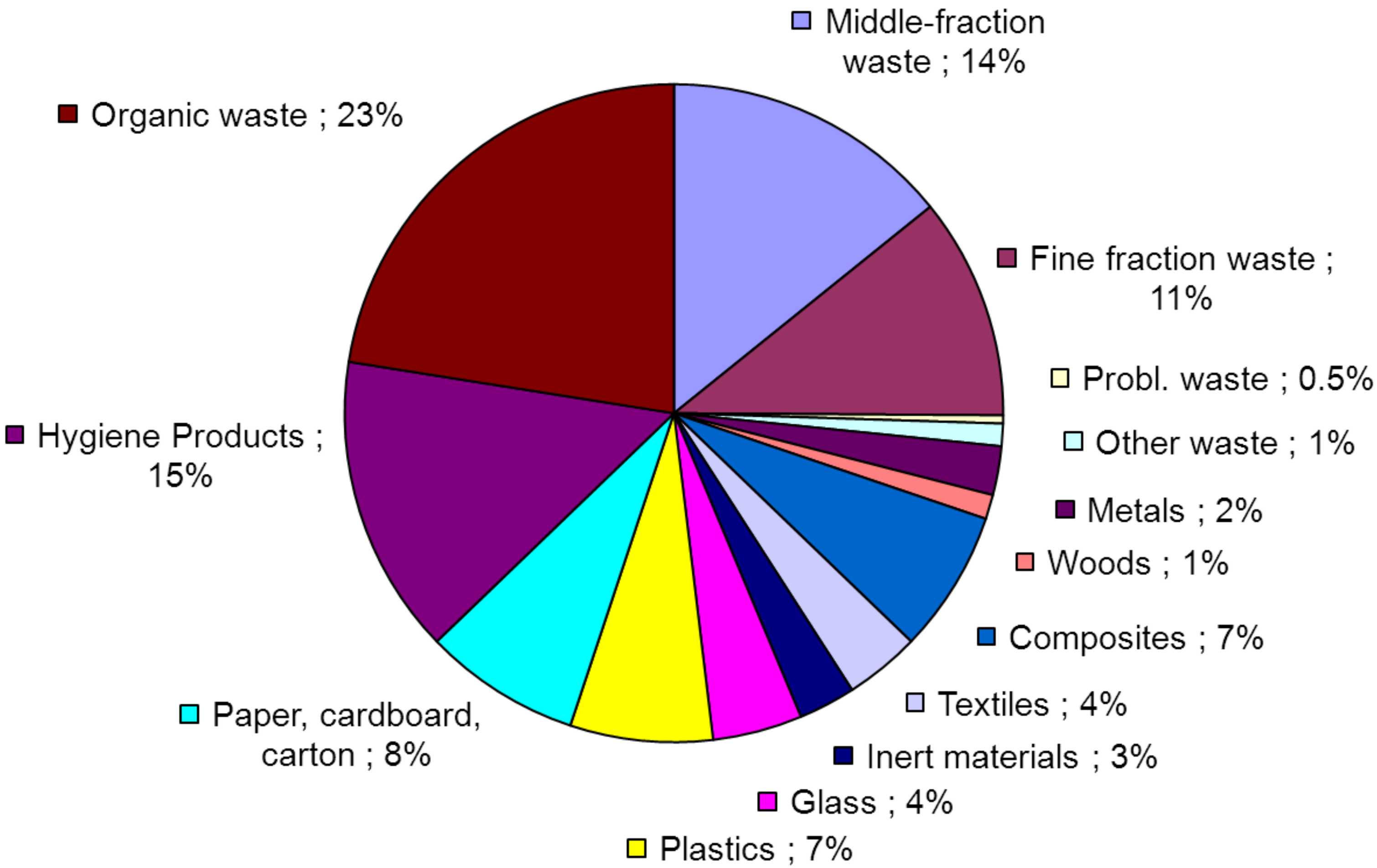
Influence of collection- and delivery system





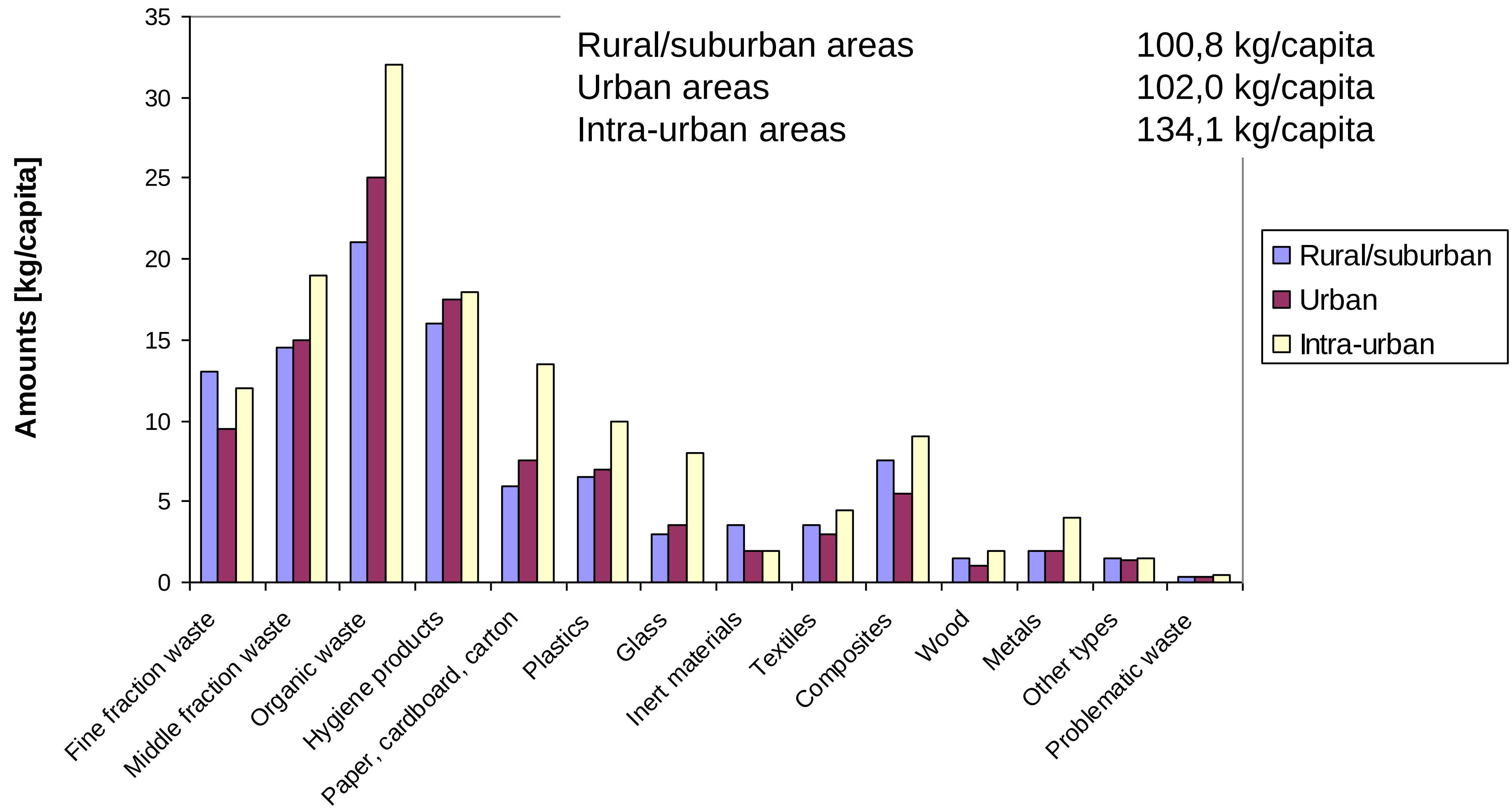


(according to Weigand , Marb: Müll und Abfall 10 (2005) 522 ff.)


Middle-fraction waste ; 14%
Fine fraction waste ; 11%
Probl. waste ; 0.5%
Other waste ; 1%
Metals ; 2%
Woods ; 1%
Composites ; 7%
Textiles ; 4%
Inert materials ; 3%
Glass ; 4%
Plastics ; 7%
Paper, cardboard, carton ; 8%
Hygiene Products ; 15%
Organic waste ; 23%

Residual waste amounts (15 Bavarian local authorities)
between 72 and 204 kg/capita (112,5 kg/capita)

Rural/suburban areas	100,8 kg/capita
Urban areas	102,0 kg/capita
Intra-urban areas	134,1 kg/capita



Waste Treatment Paths of Substance Flows in the EU in 2004

	Waste Mass flow	Waste production (potential) [Mio. Mg]	Disposal [Mio. Mg]	Recycling [Mio. Mg]	Energetic utilisation [Mio. Mg]	Utilisation rate [in %]	Recycling/energetic Utilisation + (selected) incineration [Mio. Mg]	Recycling/energetic Utilisation + (selected) incineration [in %]
1	Glass	21,6	10,9	10,7	0,0	50%	10,7	50%
2	Paper	79,5	35,3	44,2	0,0	56%	54,0	68%
3	Plastics	26,2	17,0	4,5	4,7	35%	13,7	52%
4	Iron & Steel	102,6	24,9	77,7	0,0	76%	77,7	76%
5	Aluminium	4,6	1,6	3,1	0,0	66%	3,1	66%
6	Copper	1,4	0,5	0,9	0,0	62%	0,9	62%
7	Zinc	1,2	0,5	0,7	0,0	58%	0,7	58%
8	Lead	1,0	0,4	0,6	0,0	63%	0,6	63%
9	other metals	1,2	0,7	0,5	0,0	39%	0,5	39%
10	Wood	70,5	24,7	21,7	24,0	65%	53,0	75%
11	Textiles	12,2	8,3	2,8	1,1	32%	6,2	51%
12	Rubber and used tyres	3,2	0,7	1,6	0,9	78%	2,6	82%
13	Bio-waste	87,9	55,1	28,8	4,0	37%	46,5	53%
14	Surrogate fuel	70,1	55,0	0,0	15,1	22%	29,2	42%
15	Oleaginous waste	7,4	4,4	2,2	0,8	41%	5,6	75%
16	Solvents	1,6	0,6	0,4	0,6	61%	1,5	90%
17	Ashes and slags	131,4	48,4	82,9	0,0	63%	82,9	63%
18	Mineral waste	1.794,4	1.025,2	769,2	0,0	43%	769,2	43%
	Sum	2.417,9	1.314,0	1.052,6	51,3	46%	1.271,6	48%

Impact of Pick-up and Bring Systems

- Pick-up systems lead to a significant reduction of the residual waste amounts for biogenous waste, PCC and/or LWP.
- In intra-urban areas, there are increased amounts of residual waste due to recyclable resources which are not utilised.
- The restriction of the waste container volumes reduces the amounts of residual waste to be disposed.

=> Steering instruments for a further reduction of the waste amounts

Fine-tuning between:

Acceptable efforts ⇔
available utilisation technologies ⇔
quality requirements on secondary resources

Reduction of the residual waste!

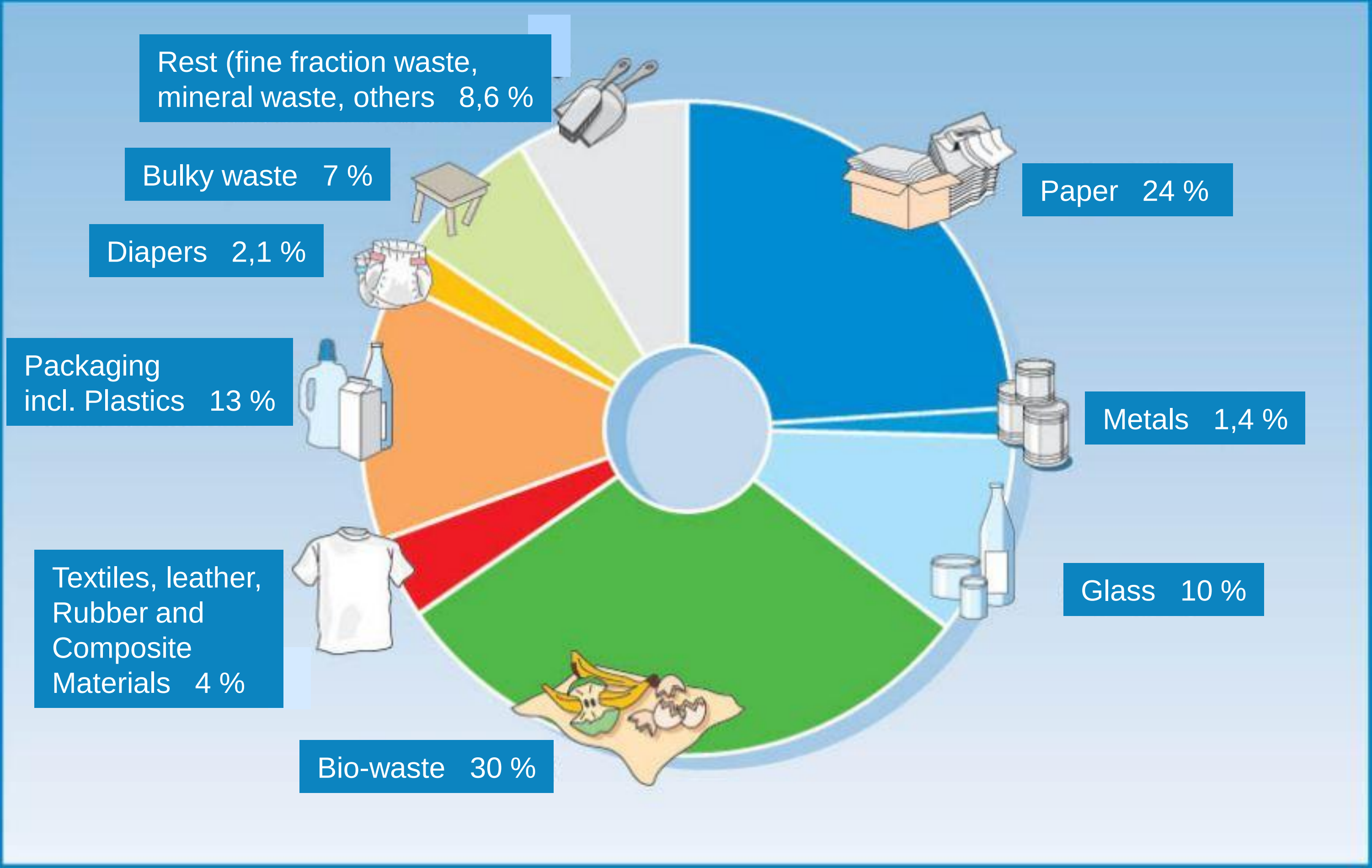
[according to Weigand , Marb: Müll und Abfall 10 (2005) 522 ff.]


1990
residual waste
87 %
34 m tonnes
Bio-waste
Glass
Paper
13 %
5 m tonnes
2004
residual waste
42 %
18 m tonnes
Bio-waste
VERPA-CKUN-GEN
Glass
Paper
58 %
25 m tonnes
2007
residual waste
38 %
16,1 m tonnes
Bio-waste
VERPA-CKUN-GEN
Glass
Paper
62 %
25,7 m tonnes

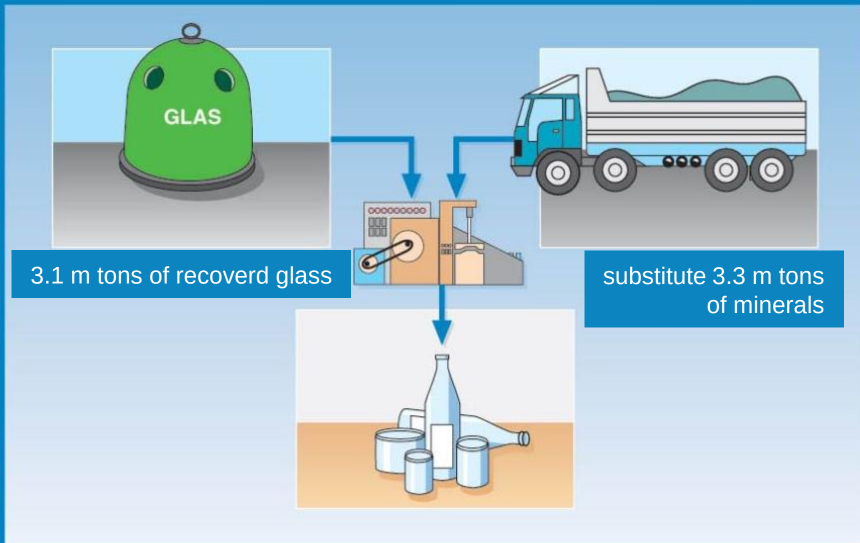
Umwelt Bundes Amt

For our Environment

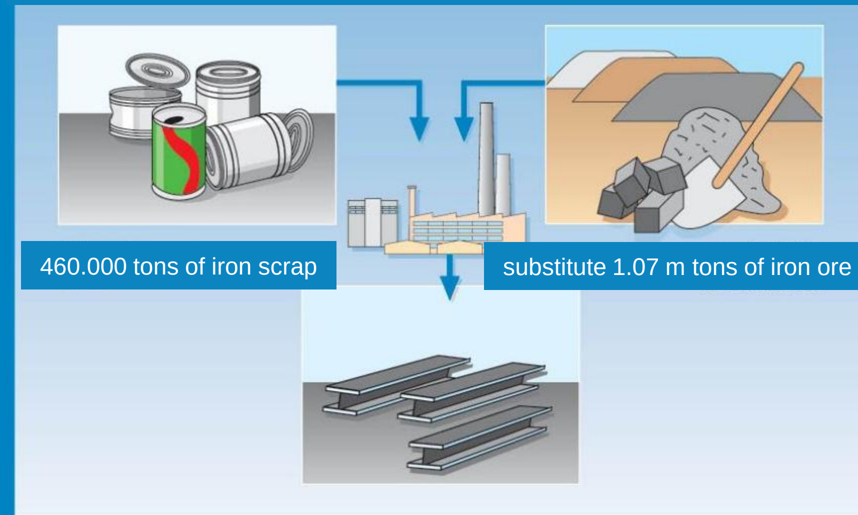
There is something good in your waste: Waste becomes a raw material source



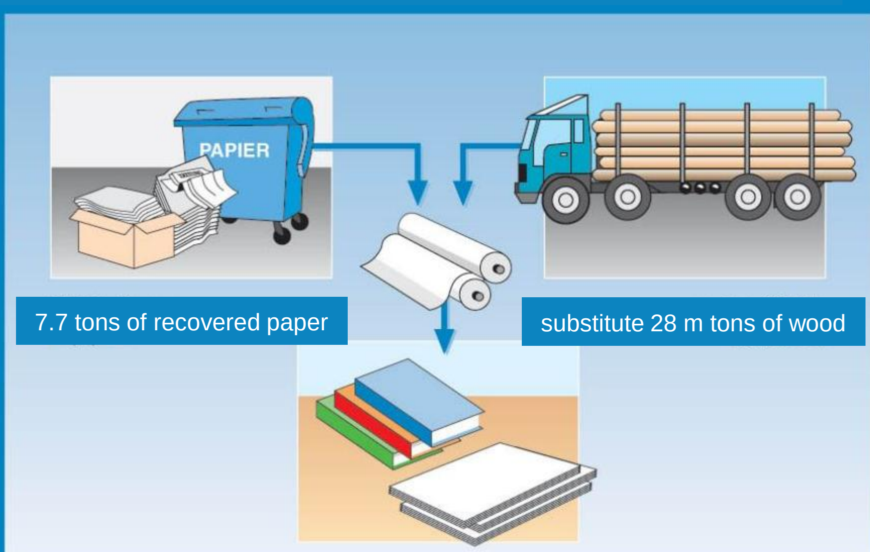
3.2 Mio ton of glass are in the cycle
Glass recycling established for years



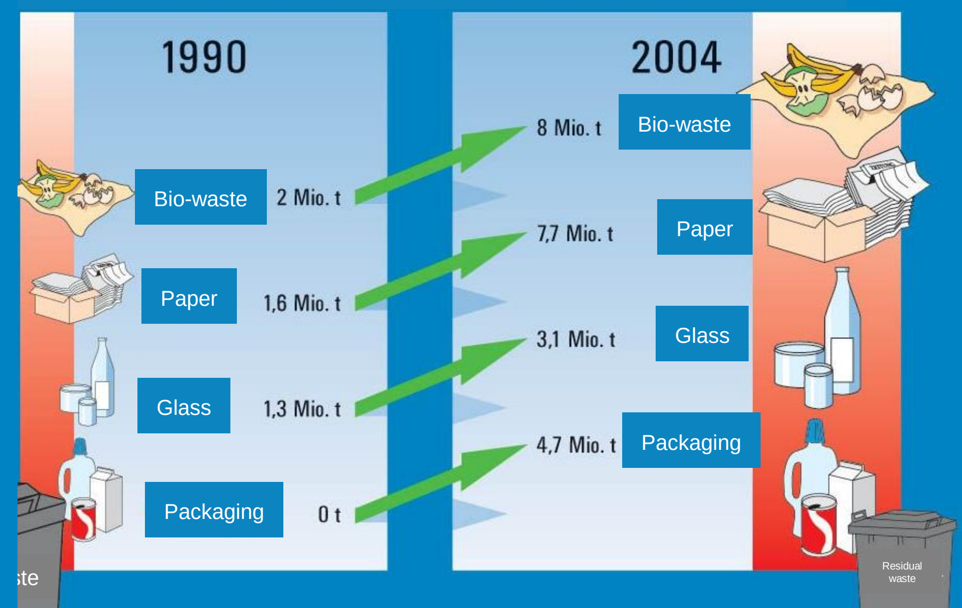
scrap metal is desireable
480.000 t of scrap metal are recycled every yea



Recycling avoids forest destruction
The alternative resource is recycled paper

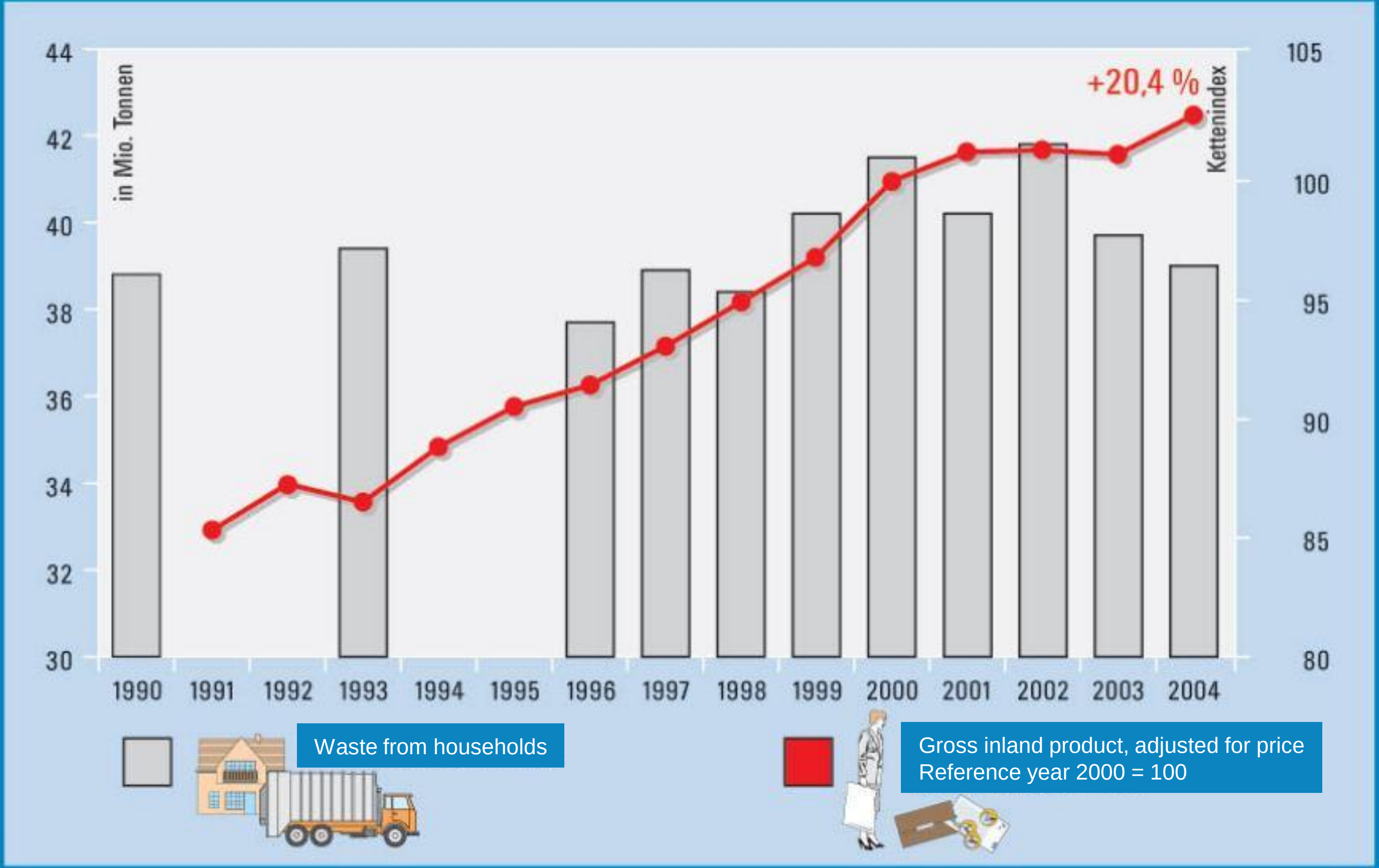


Join us: 15 Mio t recycling material more are extracted from residual waste



Umwelt Bundes Amt
For our Environment

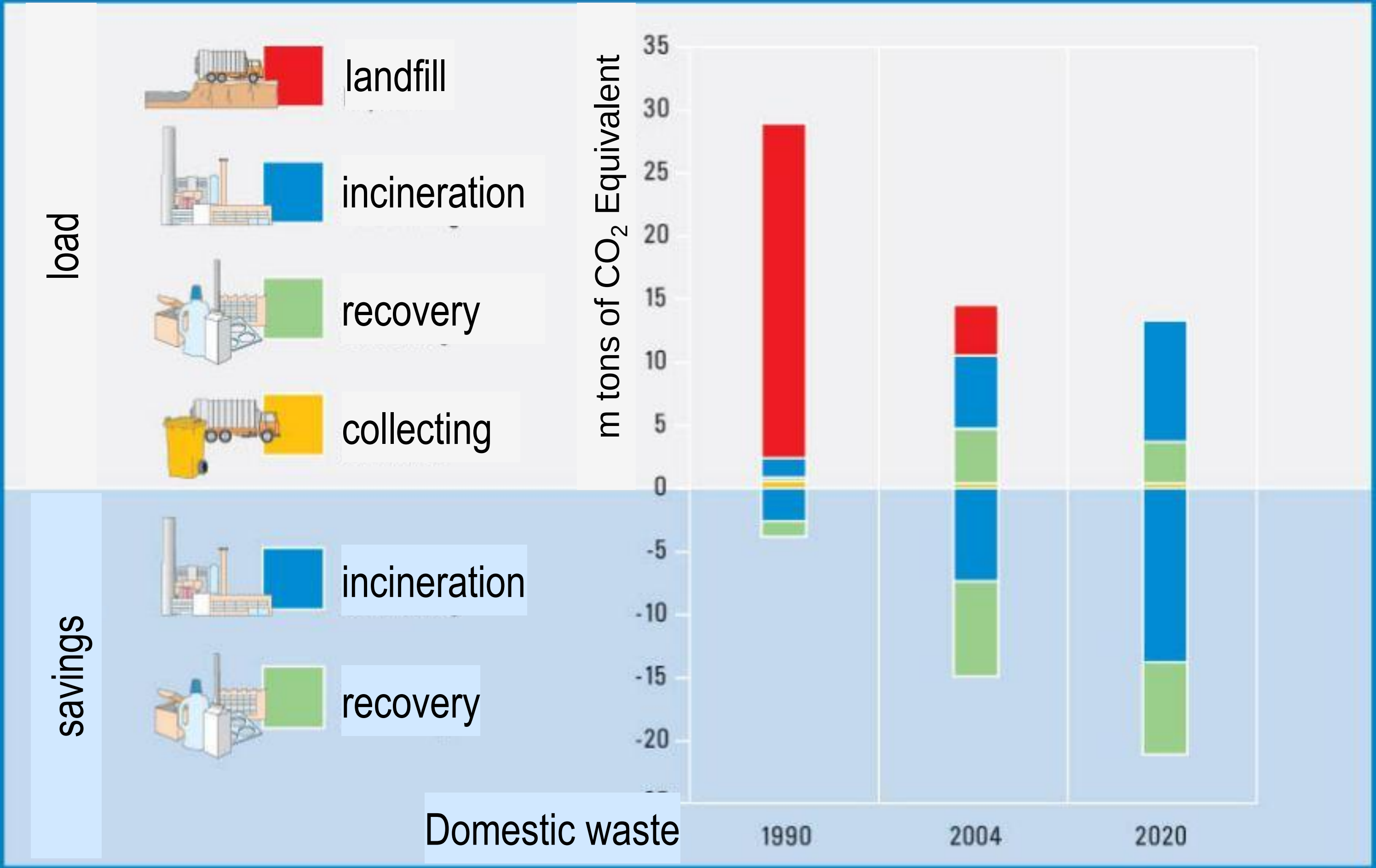
Decoupling the economic growth from waste
The economy is growing (12.5 %) – the waste amount scarcely so



Umwelt Bundes Amt

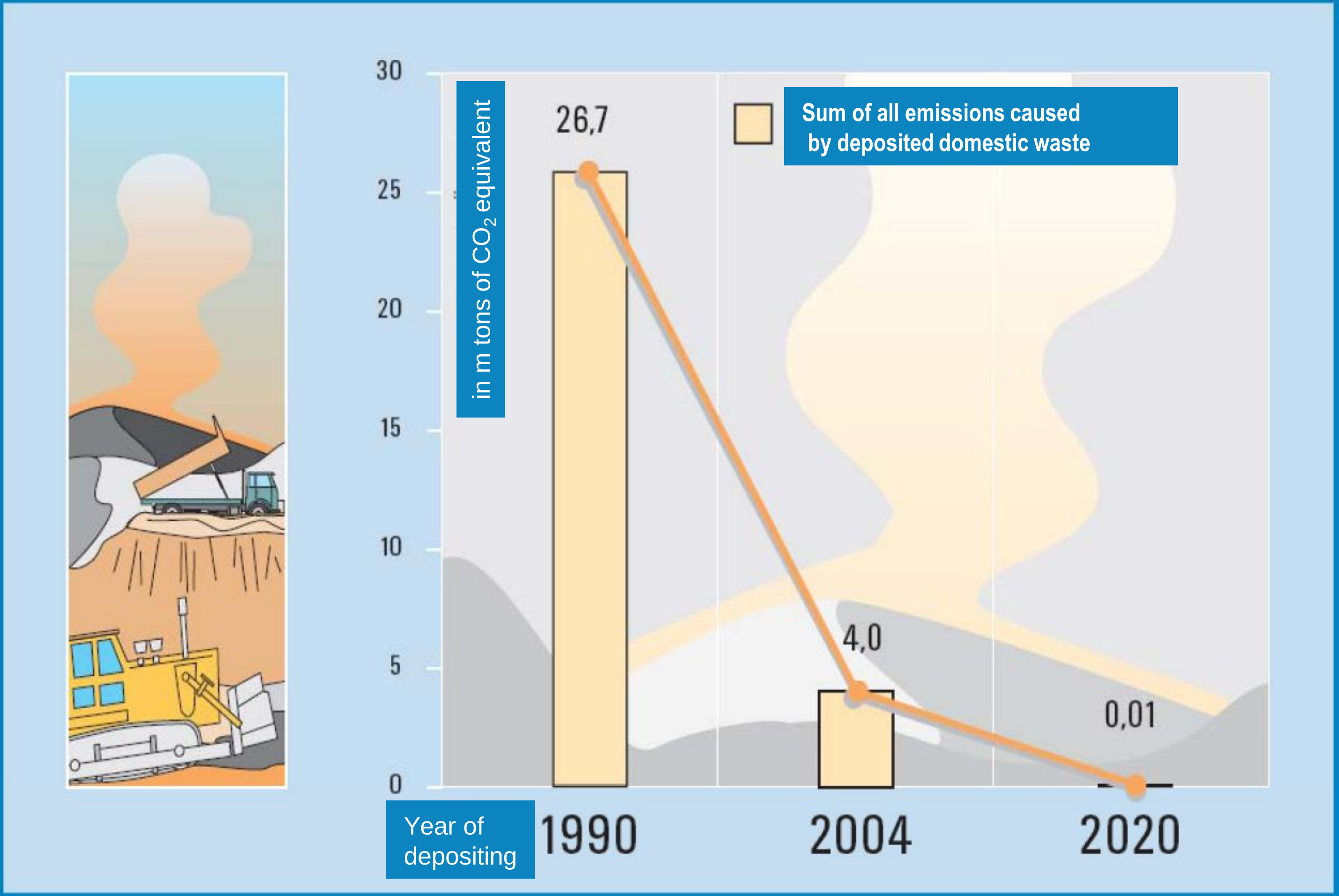
For our Environment

The main reasons for the decrease of greenhouse gas immissio
Start up of recycling improves the Balance



Federel Ministry for the
Environment, Nature Conversation
Ans Nuclear Safety

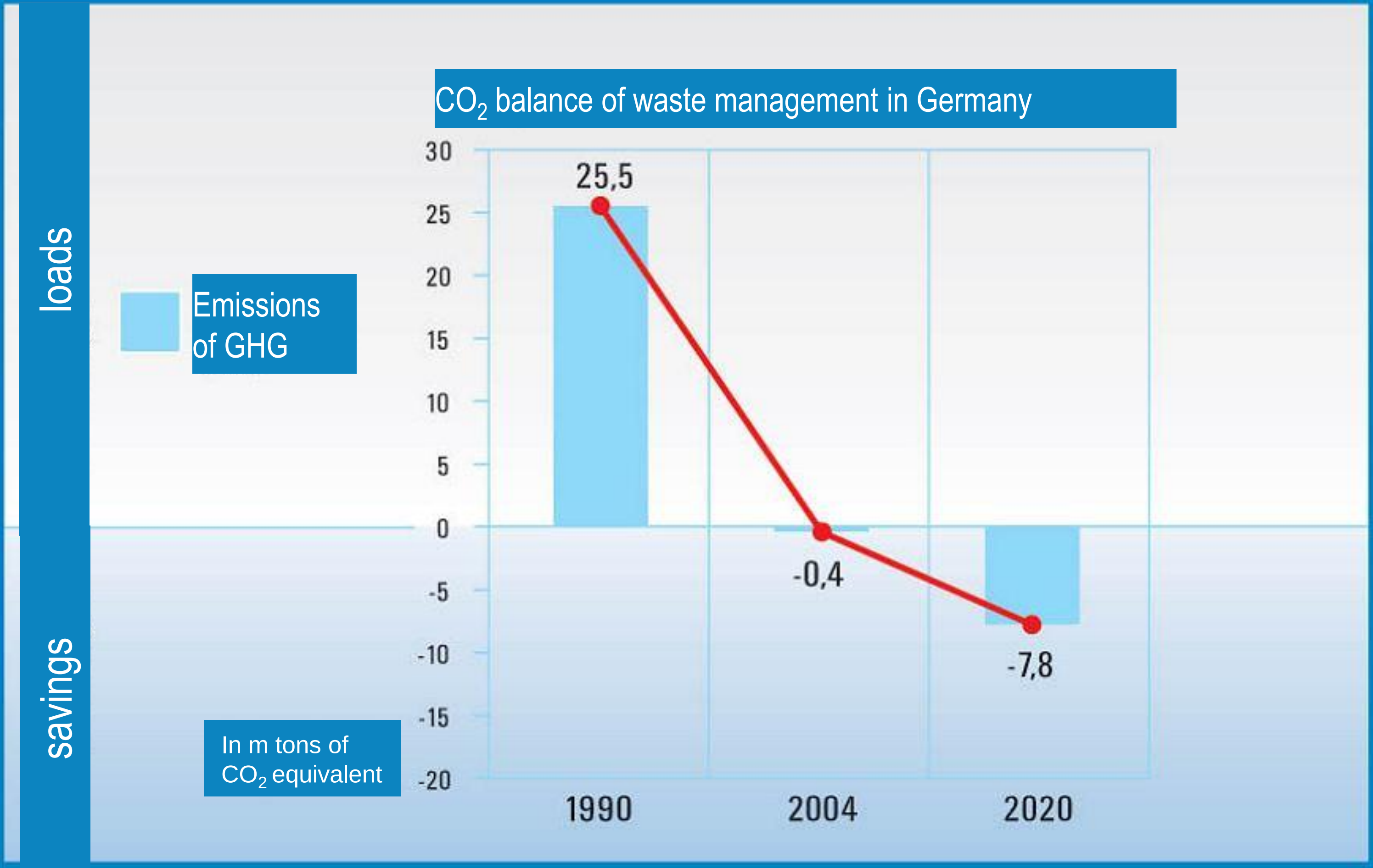
Waste deposited after 2005 emits hardly any greenhouse gas
Death of a climate killer



Umwelt Bundes Amt

For our Environment

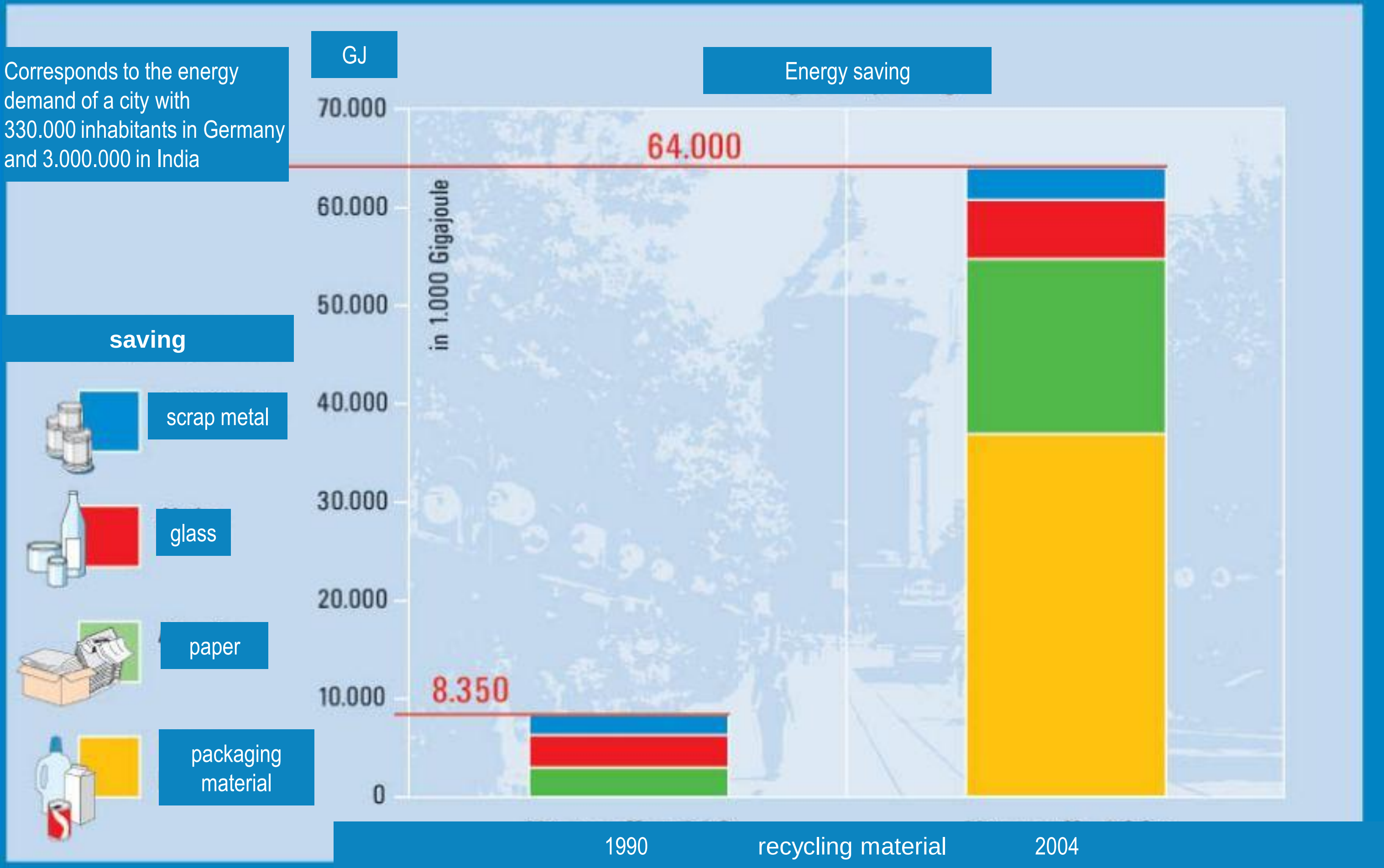
Waste Management relieves the CO_2 balance significantly



Umwelt Bundes Amt

For our Environment

Energy efficiency through recycling
The energy saved would cover the demand of a big city



Waste Weight/Waste Volume/Volumetric Weights

- **Waste Weight:** Weighed waste amounts – preconditions for any waste management planning.
  → Disposal plants with stationary balance machine.

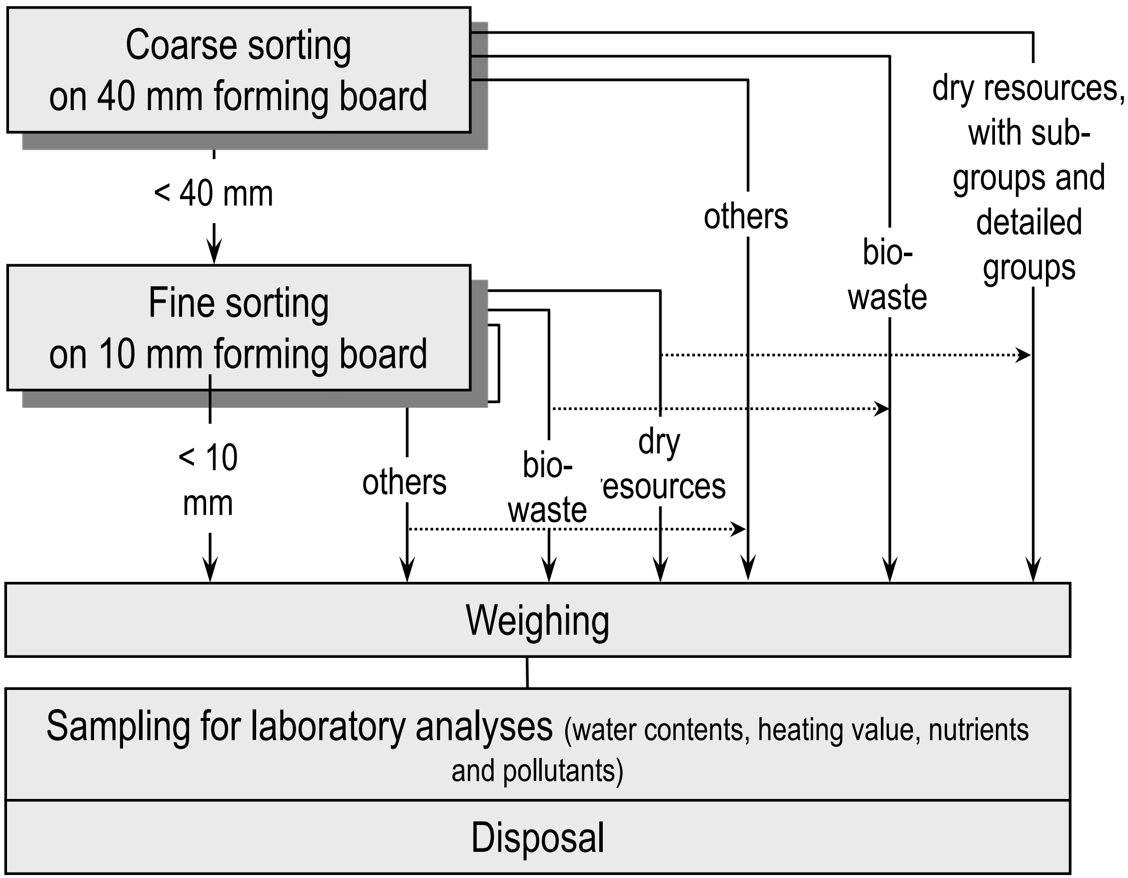
- **Waste Volume:** Data on volume and volumetric weights are necessary for the dimensioning of container sizes, bunkers and conveyor aggregates, but only sensible it at the same time the location of the volume determination is given:

Location of determination	**Volumetric weight (Mg moist mass/ m³)**
Collection container for residual domestic waste	0,08 - 0,20
Collection vehicle for residual domestic waste with compacting	0,2 - 0,5
Garbage bunker for residual municipal waste	0,2 - 0,3
Dumping ground	
- Raw waste wihtout previous mech. comminution	0,8 - 1,0
- Raw waste with previous mech. comminution	1,1 - 1,2
- after mechanical-biological treatment	1,2 – 1,5
Slags from garbage incineration	1,5
Compost from bio-waste, loosely shaken ≤ 40 mm	0,7

Composition of Waste

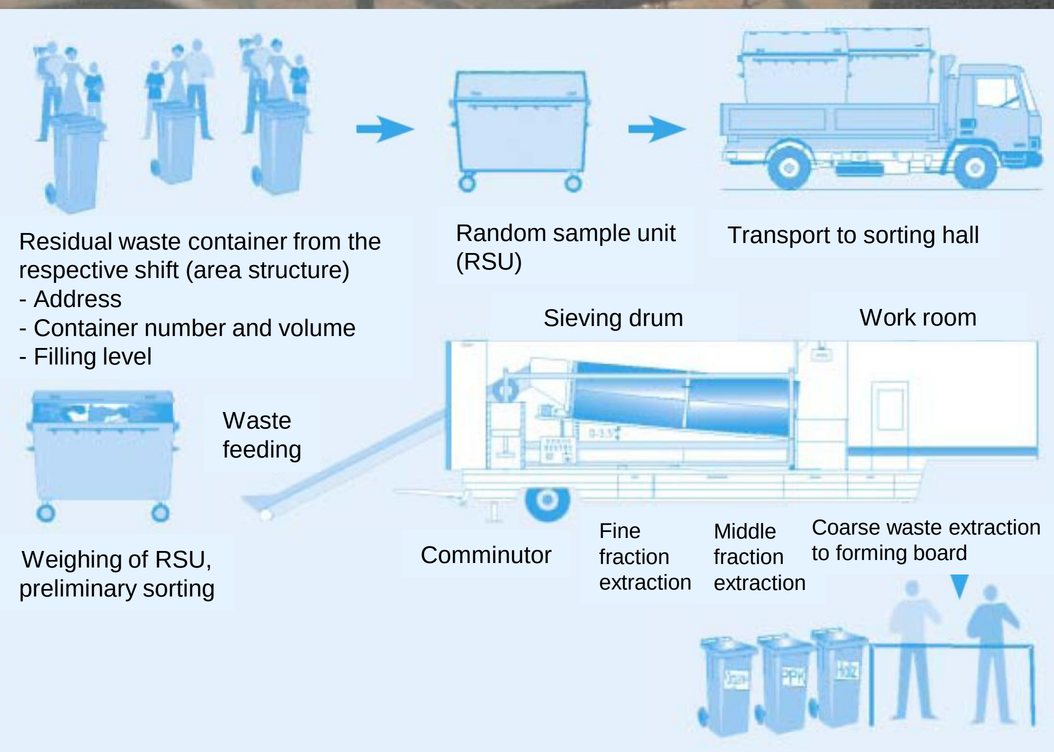
- Description of the composition of waste as follows:
  - according to types of waste: domestic waste, bulky waste, domestic waste-like commercial waste, production-specific waste, etc.
  - according to material composition
  - according to chemical, biological or physical properties
  - according to reaction behaviour
    - leachability (for depositing);
    - bio-degradability (for composting; rotting; fermentation)
    - combustible/non-combustible (heating value) for incineration
- For the **determination of the material composition**, the following methods are suitable:
  - **Manual sorting analysis (for DW and possibly BW)**
  - For domestic waste-like CW and PA **visual classification**
  - **Calculation of** average waste composition according to substance groups **from consumption data and waste paths** (secondary-statistically; mass flow balance)

Manual Sorting Analysis of Domestic Waste

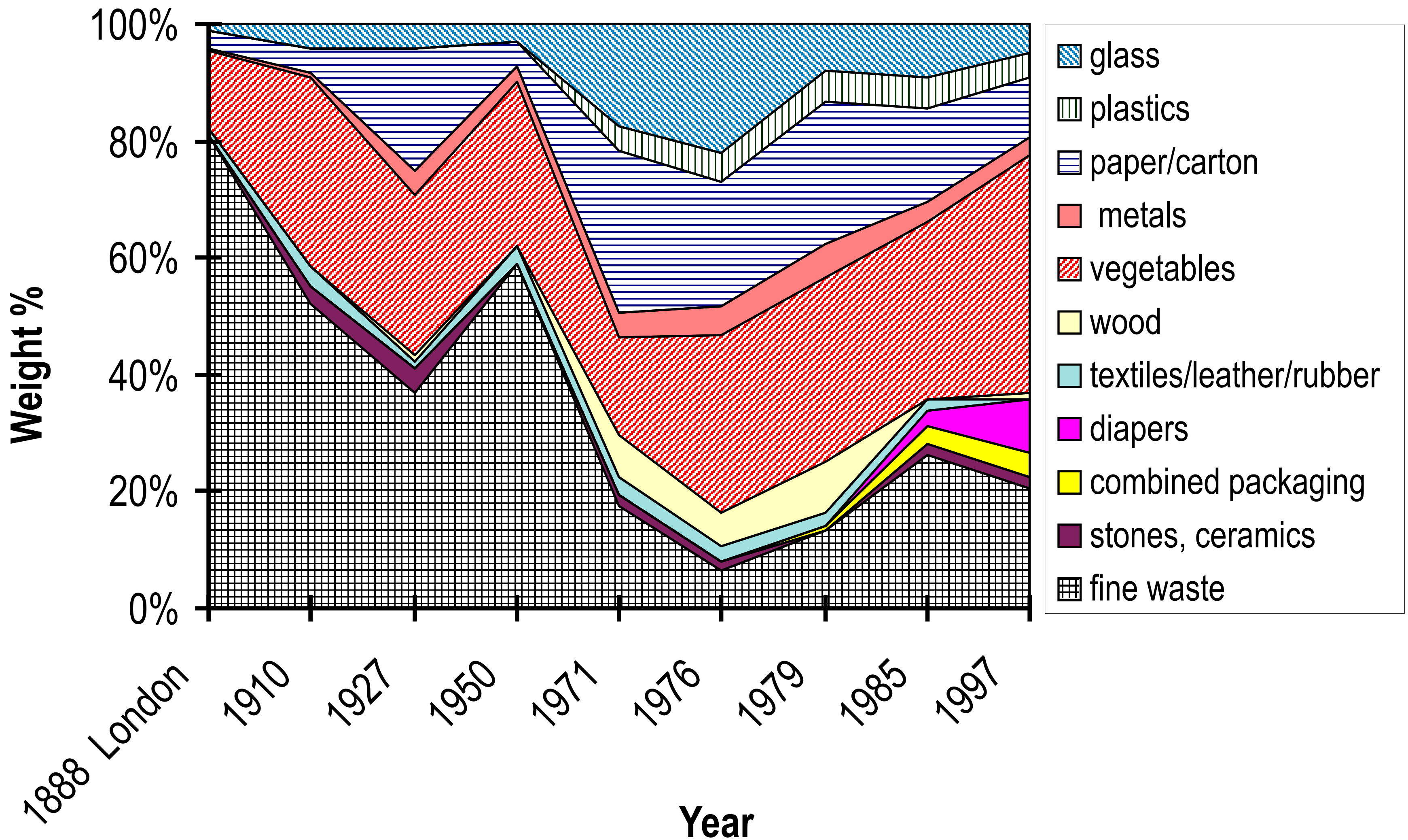


- Target: information on the utilisation status and the behaviour during treatment
- Determination of sorting groups and sorting methods
- Shift variables:
  - Settlement structure
  - Area structure
  - Container types
  - Collection system
- Determination of shift-specific collection rates and waste amounts
- Sorting rate with 8 sorters approx. 1-1,5 Mg /d
- Sortable number of containers; random selection
- 3-4 sorting runs, seasonally distributed
- Collection of the analysed waste
- Sorting, weighing, and extrapolation

Manual Sorting in Bielefeld



MSW Sorting Analysis in Germany (1888 London) HMZusammensetzung.xls



Analysed substance group	Ratio	Moisture	Caloric value	TOC	Cl	S	Cd	Cr	Cu		PAK	PCB	PCDD/F	PCPh
	%	g/kg	kJ/kg	g/kg	g/kg	g/kg	mg/kg	mg/kg	mg/kg	/kg	µg/kg	µg/kg	ng/kg	µg/kg
Fine fraction	10,88	31,5	422	11,5	0,52	0,68	0,2	21,9	17,7	,4	1.550	9,5	1,36	12,8
Middle fraction	14,24	73,2	1.066	27,2	0,58	0,43	0,3	6,8	10,4	,8	182	8,7	1,27	8,4
Electronic scrap	0,76	0,1	174	3,7	0,27	0,02	1,8	5,7	160,1	,9	73	1,4	0,03	1,5
Glass	4,47	0,4	n. b.	0,3	0,02	0,02	0,1	14,0	0,5	9	n. b.	n. b.	n. b.	n. b.
Wood	1,18	1,7	184	4,6	0,01	0,01	<0,1	0,1	0,3	7	72	4,5	0,21	17,5
Hygiene products	14,46	89,2	1.103	26,2	0,22	0,07	0,1	1,2	1,4	,8	48	1,6	0,03	3,9
Inert materials	2,49	0,6	n. b.	0,2	0,03	0,43	0,9	5,4	1,4	,1	n. b.	n. b.	n. b.	n. b.
Plastic packaging/foils	5,49	9,1	1.652	33,4	0,13	0,08	0,1	4,1	4,1	,8	76	5,2	0,07	4,8
Leather/rubber/cork	0,31	0,2	74	1,6	0,07	0,03	0,1	25,0	0,6	,3	69	0,7	0,23	19,0
Organic waste	22,47	138,8	1.520	36,9	0,75	0,19	0,2	1,7	2,9	3	52	2,8	0,98	4,8
Paper/cardboard/carton	7,90	16,0	873	22,8	0,09	0,07	0,1	1,7	3,1	7	73	5,4	0,10	12,5
Renovation waste	1,39	0,7	256	5,9	0,12	0,08	0,3	0,9	0,8	,5	68	3,5	0,23	13,4
Shoes	0,86	0,5	190	4,2	0,20	0,05	0,1	50,5	0,5	,4	69	1,9	0,20	24,0
Other types of waste	1,37	0,8	421	9,0	0,46	0,02	1,1	4,5	1,4	1	35	9,8	0,05	1,5
Other composites	2,62	2,0	509	11,8	0,32	0,14	0,6	66,8	20,2	,9	218	6,2	0,36	30,2
Vacuum cleaner bags	0,58	0,6	69	1,8	0,06	0,07	<0,1	0,8	0,5	0	12	1,5	0,13	4,9
Textiles	2,80	4,1	452	11,2	0,03	0,07	0,1	2,9	1,4	2	98	2,0	0,21	5,7
Composite packaging	1,91	3,2	342	7,4	0,07	0,02	<0,1	0,4	1,4	3	13	1,4	0,03	2,4
Rest	3,82	n. b.	n. b.	n. b.	n. b.	n. b.	n. b.	n. b.	n. b.	b.	n. b.	n. b.	n. b.	n. b.
Residual waste moist	**100**	**372,6**	**9.308**	**219,6**	**3,94**	**2,48**	**6,3**	**214,5**	**228,7**	**1,1**	**2.711**	**66**	**5,5**	**167,2**

Sampling of Waste

- According to the law of error propagation, the single variances

$$s^2 = \frac{1}{n-1} \bullet \sum (x_i - \bar{x})^2$$

will add up to a total error as follows:

$$s^2_{total} = s^2_{Sampling} + s^2_{Sample\,processing} + s^2_{Measuring/Analytics}$$

- Sampling is problematic because of the great heterogeneity.
- Sampling should
  1. yield a representative sample
  2. ideally be done with as little time demand and technical efforts as possible
- **Single sample**: sample taken in one work step at one location
- **Mixed sample:** accrued and mixed from single samples
- **Collective sample**: accrued and mixed from mixed sample
- **Subsample**: sample gained after dividision to reduce the sampling volume

Sampling Number and Amounts

- Determination of sample number and sample amounts according to LAGA PN 2/78 and 2/78 K

max. grain size of the waste	**Minimum number of single samples**					
	from moved waste		from static waste			
			In trucks	in stores		
	up to 50 t	bigger than 50 t		up to 50 t	50 to 150 t	bigger than 150 t
< 20 mm	3	3 per 50 t	3	3	3 je 50 t	8
> 20 mm	5	1 per 10 t	per truck	5	1 je 10 t	15

- The required minimum weight of the single sample depends on the maximum grain size and the homogeneity of the respective waste, according to the LAGA Directives according to the following approximation formula:
- G[kg] = 0,06 * d [mm]
- If collective samples gained from single samples are divided in order to reduce the sample amount, the minimum mass of the single sample has to comply with the requirements of the following table.

Upper grain size of the sample	**Minimum mass of the subsample**	
	Mainly homogeneous material	**Very heterogeneous material**
[mm]	**[kg]**	**[kg]**
120	50	200
30	10	30
10	1	1,5
3	0,15	0,15

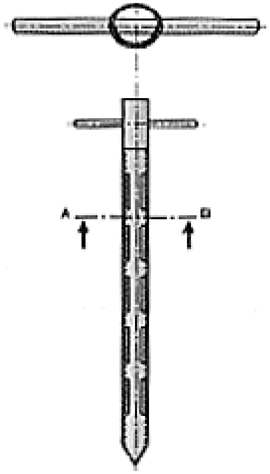
Minimum number and volume of the single/mixed/collective/ and lab samples according to LAGA PN 98

Volume of the basic amount	Number of single samples	Number of mixed samples	Number of collective samples	Number* of lab samples
up to 30 m3	8	2	none	2
up to 60 m3	12	3	none	3
up to 100 m3	16	4	none	4
up to 150 m3	20	5	none	5
up to 200 m3	24	6	none	6
up to 300 m3	28	7	none	7
up to 400 m3	32	8	none	8
up to 500 m3	36	9	none	9
up to 600 m3	40	10	none	10
up to 700 m3	44	10 + (1)	1	11
up to 800 m3	48	10 + (2)	1	11
up to 900 m3	52	10 + (3)	1	11
up to 1000 m3	56	10 + (4)	2	12
up to 1100 m3	60	10 + (5)	2	12
up to 1200 m3	64	10 + (6)	2	12
		1 per each inchoate 100 m3	1 per each inchoate 300 m3	1 per each inchoate 300 m3

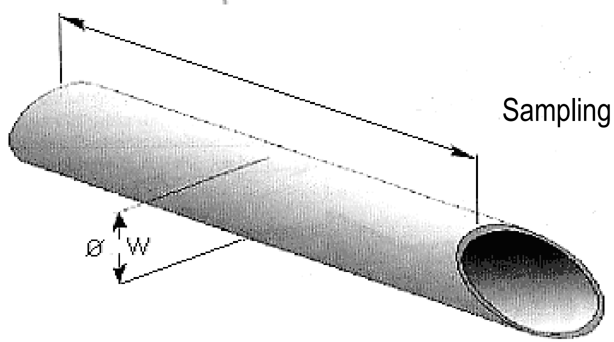
Maximum grain size / particle size [mm]	Minimum volume in the single sample [in l]	Minimum volume in the lab sample * [in l]
≤ 2	0,5	1
>2 to ≤20	1	2
>20 to ≤ 50	2	4
>50 to ≤ 120	5	10
> 120	Piece = Single sample	Piece = Single sample

Sampling Tools according to LAGA PN 98

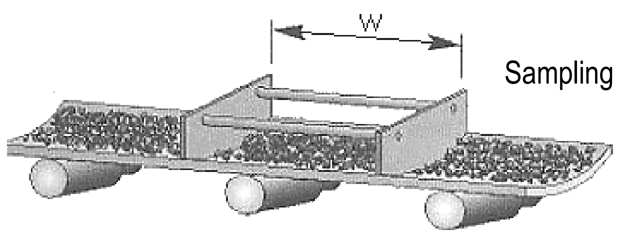
Cross section A-B (enlarged)



Sampling pipe

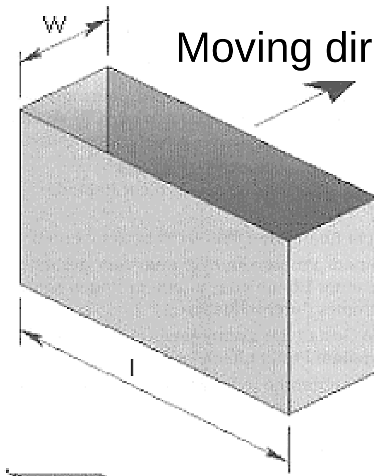


Sampling lancet

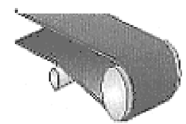


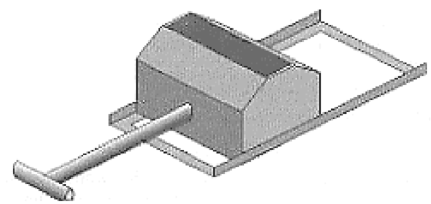
Sampling plug

Moving direction during operation

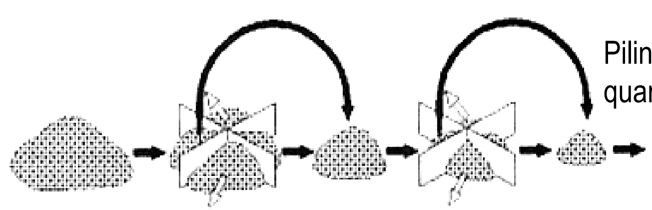


Sampling collection box



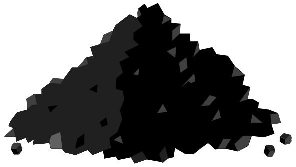
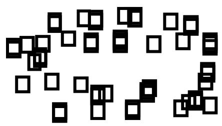
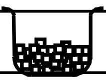
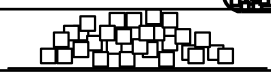
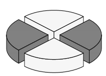
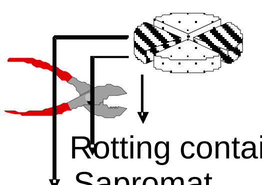


Manually controlled sampling drawer

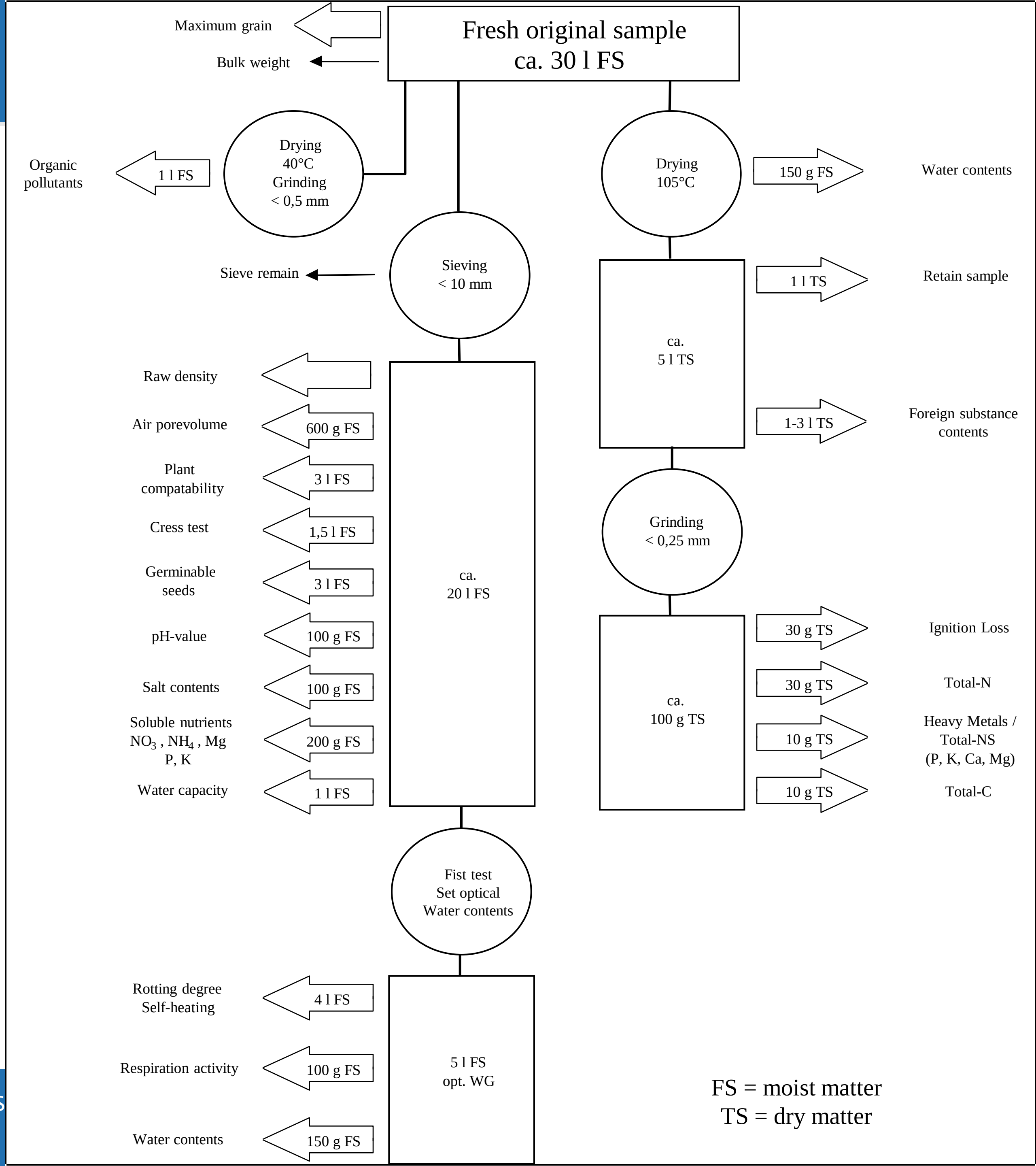


Piling-up and quartering

Sample-Taking and Processing

Material	Mass	Reduction factor	Annotations
Basic amount 	e.g. contents of one dumptruck ca. 20 m^3 or 8 - 12 t	1	heterogeneous pluri-substance mixture max. frain diameter >> 200 mm
Single sample 	ISAH: 20 - 60x 1,0 - 1,5 kg TASI: 4 x 1,0 kg	10^{-2} - 10^{-3} 10^{-4}	Influence of the de-mixing, sampling devices, and more
Sub sample 	"	"	Accruing of the single samples
	"	"	Mixing
Sub sample 	Each cut in half	Each cut in half halbiert	If necessary, multiple reduction with the quartering method
 Rotting container Sapromat Water contents Ignition lost TOC AOS COD Other parameters	7.000 - 10.000 g 200 g 500 g 10 - 30 g 1 g 0,3 - 0,6 g 0,002 g	10^{-3} - 10^{-4} 10^{-5} 10^{-5} 10^{-6} 10^{-7} 10^{-7} 10^{-10}	Comminution to a max. grain diameter of < 10 mm < 10 mm no specification < 1 mm < 1 mm < 0,63 mm < 0,2 mm

Sample processing and amounts for compost



Chemical, biological, and physical waste analytics

- Evaluation of the behaviour of waste during disposal with chemical, biological, and physical waste analytics

- The chemical analysis refers to the examination of
  - solid substance samples of the original sample (mg / kg OS),
  - leachates of the original substance for the assessment of the depositing behaviour (mg/l leachate), or
  - Solid substance samples of all (extensively homogenised) residual substances from treatment plants (as here the taking and processing of sample is considerably alleviated) with retrograde calculation to the original substance OS

- The analysis methods to be used for waste examination (for instance DIN, EN or ISO norms) are quoted or described in any law which defines limit values, such as the Waste Depositing Regulation of 2001, etc.

Elution Tests

The evaluation of the dumping capability and allocation of waste to the depositing categories, for instance according to the Waste Storage Ordinance (AbfAblV), is based mainly on the elution behaviour, which is influenced by the

- grain size of the waste
- water/solids ratio (L/S = **L**iquid / **S**olids)
- elution agents (aqua dist.; potable water, acidic or alkaline milieu)
- intensity of the elution (static; shaken; percolated)

Obligatory in Germany: **Elutiontest according to DIN 38014 S4**:

1 part (ca. 100 g) of waste (particles > 10 mm must be disintegrated previously);
+ 10 parts (ca. 1000 g) aqua dist;
shaken in an upside-down 2 L wide mouth bottle for 24 hours;
pH-value uncontrolled and unbuffered as function of the eluted waste;
analysis of the filtered eluate

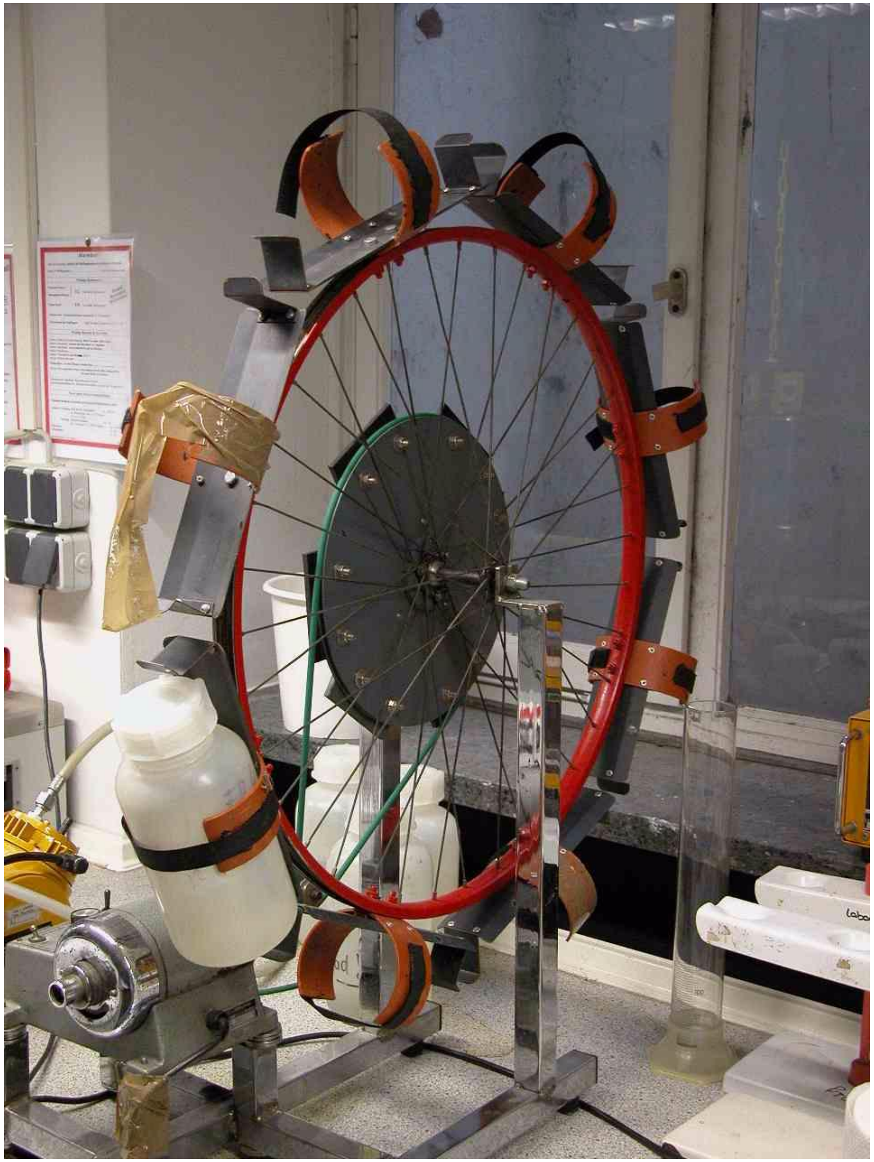
Elution Tests

An alternative to DIN 38014 S4 is the **Swiss Eluate Test** (pH-Stat-Test) with CO_2 gassing, which makes for considerably higher elution degrees due to the acidification to a statically acidic pH-value. Also possible: elution at pH-Stat 4 (HNO_3) and pH 11 (NaOH).

1 part (ca. 100 - 200 g) of waste, cylindrical test specimen, if need be produced with binding agents;
+ 10 parts (ca. 1-2 L) aqua dist., acidified to pH 4-5 through CO_2 gassing;
eluted for 24 and 48 hours, with continuous gassing with CO_2 (stirring effect, secondary acidification), shaken;
analysis of the filtered eluate

Due to the less favourable surface/volume and water/waste MW/Mwaste ratios and the higher elution intensity, the DEV test and the Swiss test make for a strongly increased elution (mg/kg waste) compared to the actual dumping ground or the dumping ground trickling water (cf. Chapter 11 Depositing), which can be simulated rather with column elution tests (percolation or lysimeter) or dumping ground simulation reactors.

Elution Apparatus of the ISAH



Analytic Values of Residual Municipal Waste

Doedens / v.Felde, 1997, AWRW

Parameter	Original substance (Literature evaluation acc. to DOEDENS/ v. FELDE, 1997) Unit	min	max	Average	Eluate acc. To DIN 38414-S4 Unit	Range	TI MW Appendix B DK I	DK II	TI Waste Appendix D
Ignition loss	weight % of DR			55-70	weight.%		< 3%	< 5%	< 10 %
TOC, (total org. carb.)	kg/Mg Waste	160	260	220	mg/L	1.000 - 2.000	< 1 %	< 3 %	k.A.
COD	kgO_2/Mg Waste			600-1400	mg/L	1.000-6.000			
Sulphurous	g/Mg Waste	700	4.500	1.500	mg/L				
Sulphurous organic	g/Mg Waste	610	700	650					
Nitrogen	g/Mg Waste			10 - 20	mg/L				
Chlorine	g/Mg Waste	2.000	10.000	7.500	mg/L	200 - 800			
Chlorine organic	g/Mg Waste	3.000	3.200	3.100	mg/L	0,5 - 2			
Fluoride	g/Mg Waste	12	500	150	mg/L		< 5	< 25	< 50
Fluoride organic	g/Mg Waste	8	13	10					

Analytic Values of Residual Municipal Waste

Doedens / v.Felde, 1997, AWRW

Parameter	Original substance (Literature evaluation acc. To DOEDENS/ v. FELDE, 1997)				Eluate acc. to DIN 38414-S4		TI MW Appendix B		TI Waste Appendix D
	Unit	min	max	Average	Unit	Range	DK I	DK II	
Metals									
As	g/Mg Waste	0,7	6,3	3	mg/L	0,02 - 0,054	< 0,2	< 0,5	< 1
Cd	g/Mg Waste	2	20	5	mg/L	0,001 -.0,012	< 0,05	< 0,1	< 0,5
Cr	g/Mg Waste	30	640	100	mg/L	0,02 -0,08	< 0,05	< 0,1	< 0,5
Cu	g/Mg Waste	100	1.000	800	mg/L	0,029 - 0,24	< 1	< 5	< 10
Hg	g/Mg Waste	0,02	5	3	mg/L	0,0002 - 0,0004	< 0,005	< 0,02	< 0,1
Ni	g/Mg Waste	17	190	50	mg/L	0,05 - 0,22	< 0,2	< 1	< 2
Pb	g/Mg Waste	140	3.000	450	mg/L	0,002 - 0,1	< 0,2	< 1	< 2
Sn	g/Mg Waste			120	mg/L				
Zn	g/Mg Waste	300	4.000	1.000	mg/L	0,45 - 3,1	< 2	< 5	< 10

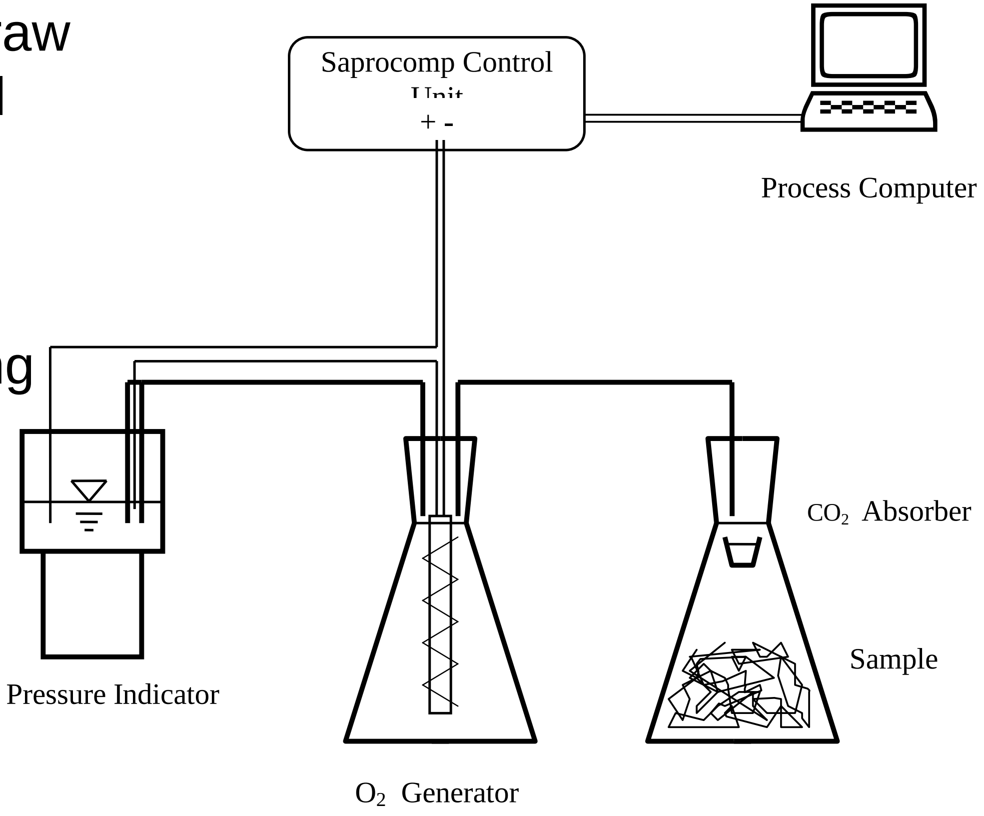
Analytic Values of Residual Municipal Waste

Doedens / v.Felde, 1997, AWRW

	Original substance (Literature evaluation acc. to DOEDENS/ v. FELDE, 1997)				Eluate acc. To DIN 38414-S4		TI MW Appendix B		TI Waste Appendix D
Parameter	Unit	min	max	Average	Unit	Range	DK I	DK II	
organic pollutants									
Dioxine	g/Mg Waste	5	15	9,4					
Dioxine/Furane	g/Mg Waste			5,5					
Dioxine/Furane	µg TE/Mg			50					
Furane	mg/Mg	0	1	0,4					
Σ PCB * 5	g/Mg Waste	0,1	10	1					
Σ 6 PAH	g/Mg Waste			34					
FCKW R11/R12	g/Mg Waste			100					
Chlorobenzenes	g/Mg Waste	0	0,6	0,05					
Carbolic acids	g/Mg Waste	0	5	2,1	mg/L	<0,1 - 1,6	< 0,2	< 50	< 100
Chlorophenols	g/Mg Waste	0,07	1,3	1					

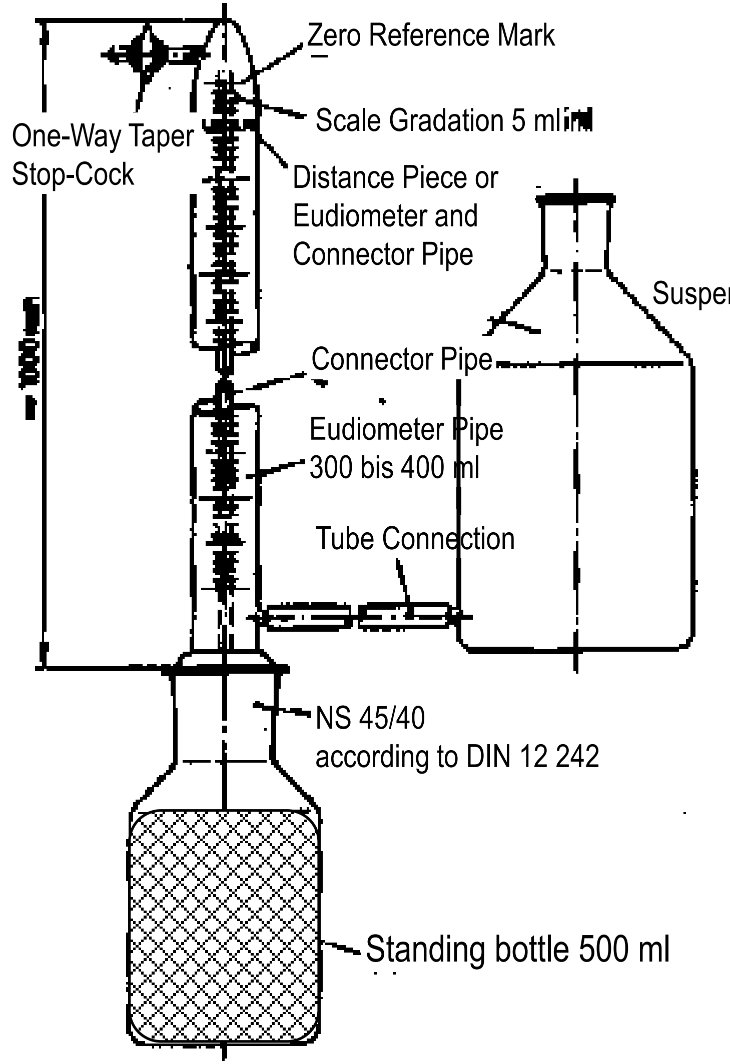
Biological Activity – Respiration Activity in the Sapromat

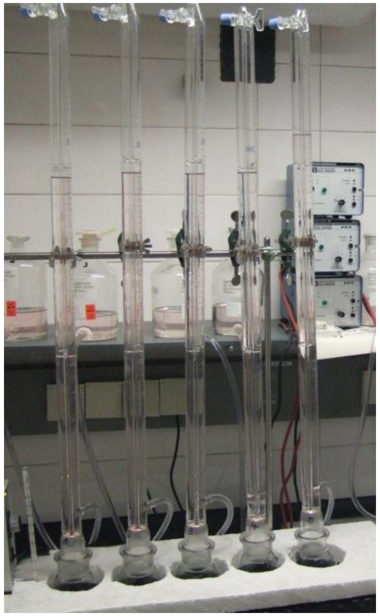
- Respiration activity RA_4 (AT_4)
  - 70 to 100 mg O_2 / g DM for raw domestic waste
  - 15 to 30 mg O_2 / g DM for raw bulky waste and commercial waste
  - ≤ 5 mg O_2 / g DM for mechanically-biologically treated waste after depositing (according to AbfAblV)



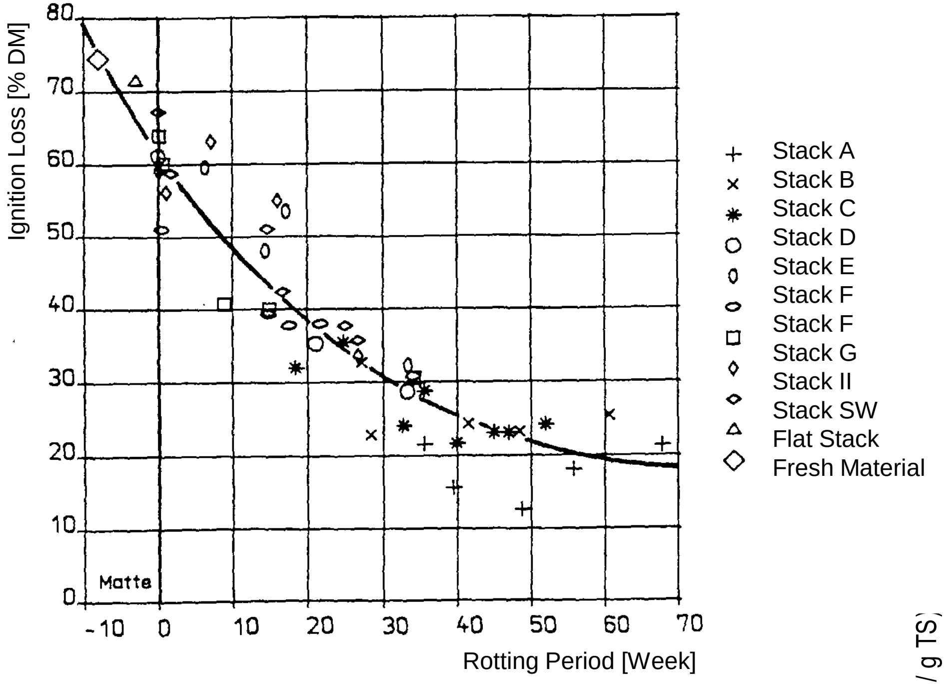
Biological Activity – Fermentation Test according to DIN 38414 - S8

- Gas production GP_{21}
  - approx. 100 - 250 L_N/kg DM for raw domestic waste
  - ≤ 20 L_N/ kg DM for mechanically-biologically treated waste for depositing (according to AbfAblV)

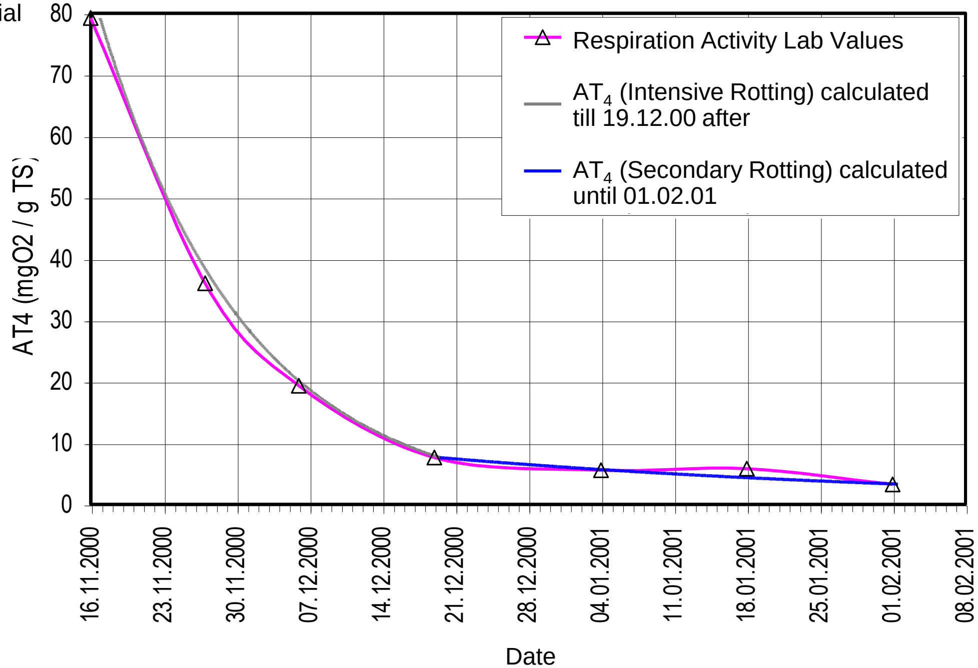




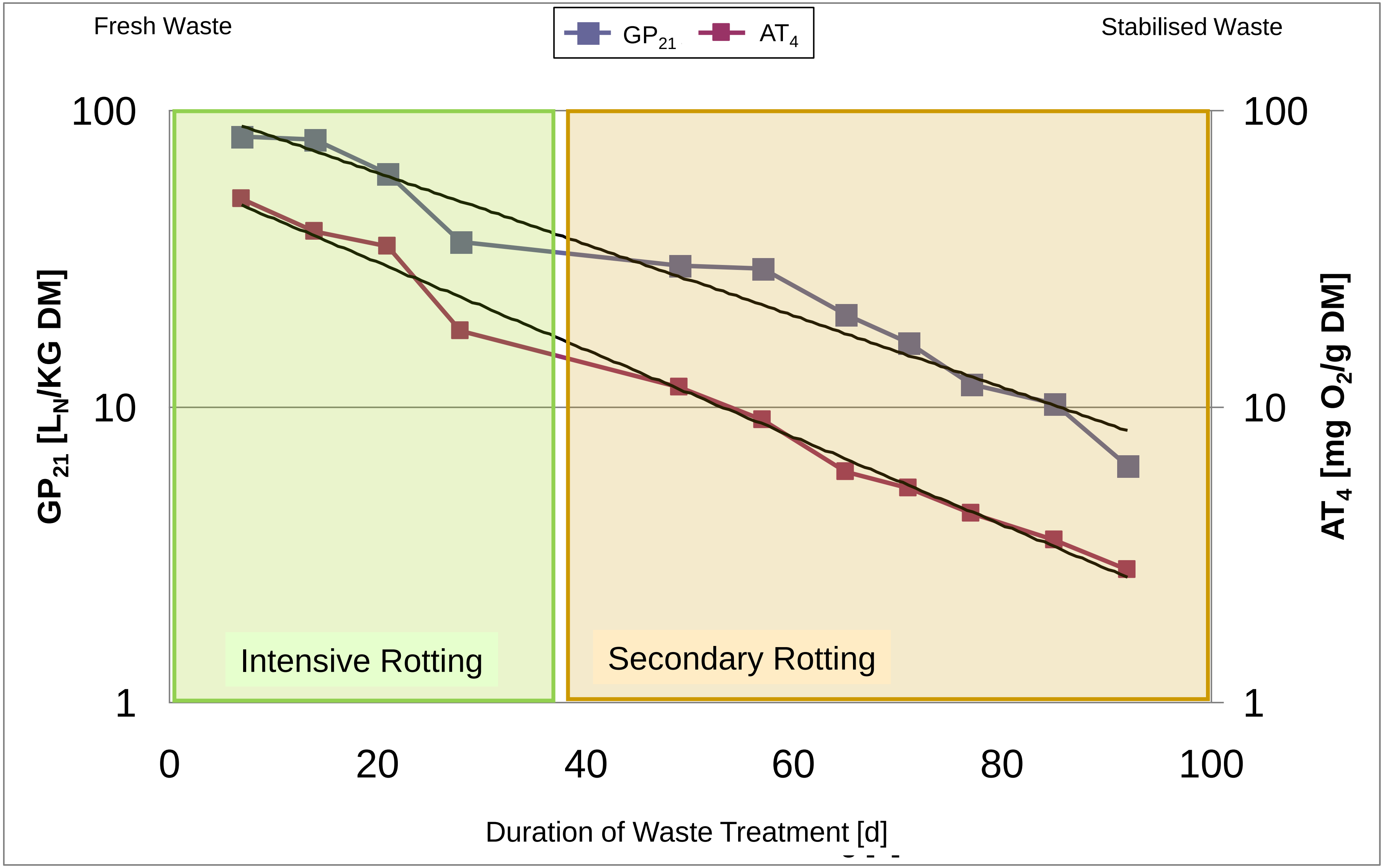
Decrease of Ignition Loss and AT_4



$$AT_4(t) = 79{,}2 * e^{-0{,}002997 * t}$$



Decrease of GP_{21} and AT_4



Water Contents and Ignition Loss

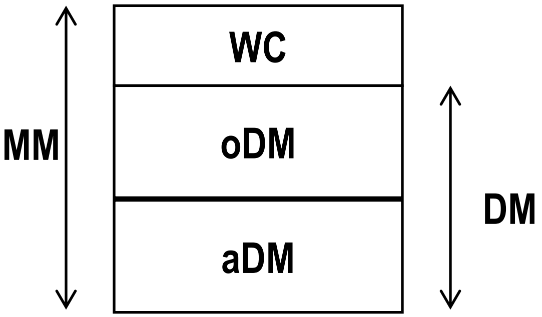
Water contents determination in the cabinet dryer at 105 °C for 2 days.

$$\text{Water contents (WC)} = \frac{\text{Moist Matter (MM)} - \text{Dry Matter (DM)}}{\text{Moist Matter (MM)}}$$

Determination of the **Ignition Loss IL** according to DIN 38414 S3 in the annealing furnace at 550 °C for 4 hours.

$$\text{IL (\% of the dry matter)} = \frac{\text{Moist Matter - Water - Ashes}}{\text{Dry Matter}} \cdot 100 = \frac{m_b - m_c}{m_b - m_a} \cdot 100 = \frac{oDM}{DM}$$

m_a	Mass of the empty crucible in g
m_b	Mass of the crucible with the dry matter in g
m_c	Mass of the crucible with the annealed dry matter in g
oDM	dry matter
aDM or min DM	inorganic or mineral dry matter

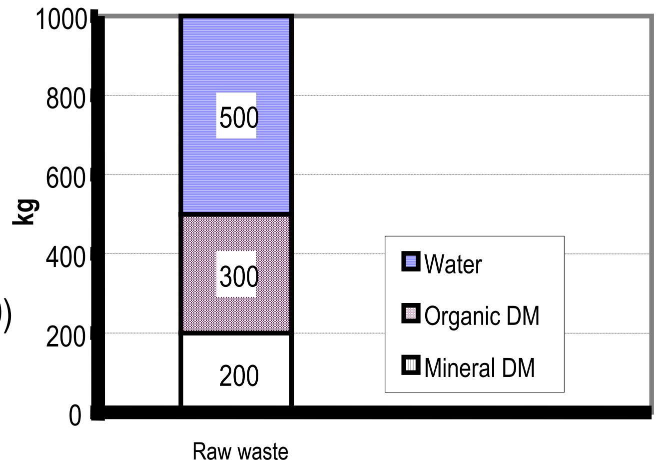


Example:

Water contents = (1000 - 500) / 1000 = 50%

Ignition loss = (1000 - 500 - 200) / (200 + 300)

= 300 / 500 = 60 %



Heating value H_u and Calorific Value H_o

Caloric value H_u (kJ/kg) Quotient of the amount of heat released during complete combustion, with the water contained in the waste and the water produced from the hydrogen contained in the waste prevailing as gases after combustion. Waste and combustion products are available at 25°C. Hu(raw) is the energy actually available in the incineration of waste.

Gross caloric value H_o (kJ/kg) as with H_u, but with the water contained in the waste and produced by the hydrogen contained in the waste being available after combustion in liquid form (condensed).

Gross caloric value H_o (kJ/kg) = **Caloric value** H_u (kJ/kg) + Evaporation enthalpy of the mass condensed from the exhaust gas

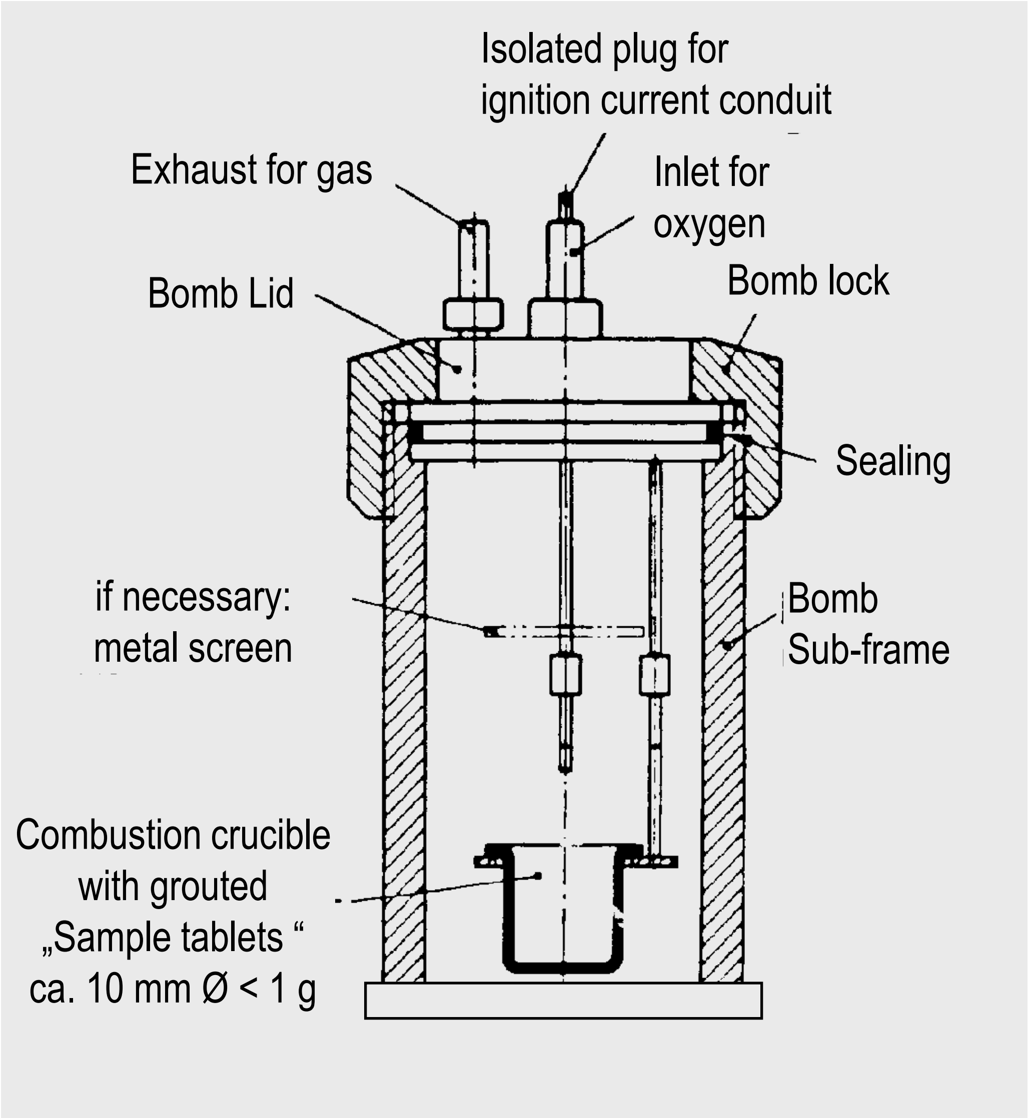
$H_{u,waf}$	(kJ/kg oDM)	Heating value free of water and ashes
$H_{u,wf}$	(kJ/kg DM)	Heating value free of water = $H_{u,waf} \cdot IL/100$

$$H_{u,raw}\ (\text{kJ/kg moist}) = \text{Heating value raw} = H_{u,wf} \cdot \frac{100 - w}{100} - 24{,}41 \cdot W$$

- IL Ignition loss (% of the dry matter) = 1-A
- A Mass ratio of the ashes in the total dry matter
- W Mass ratio of the water in the total mass (%)
- k 24,41 = (heat amount) thermal energy (2441 kJ/kg) for the heating of the water (25°C until evaporation) and for the evaporation per % W
- w Analysis moisture of the total volume (%)
- f_m Mineral factor = Mineral substances/Ashes

Calorimeter according to DIN 51 900 Parts 2 and 3

- Determination of the calorific value H_o in the **calorimeter** as quotient of the heat amount released during complete combustion and the fuel volume in kJ / kg

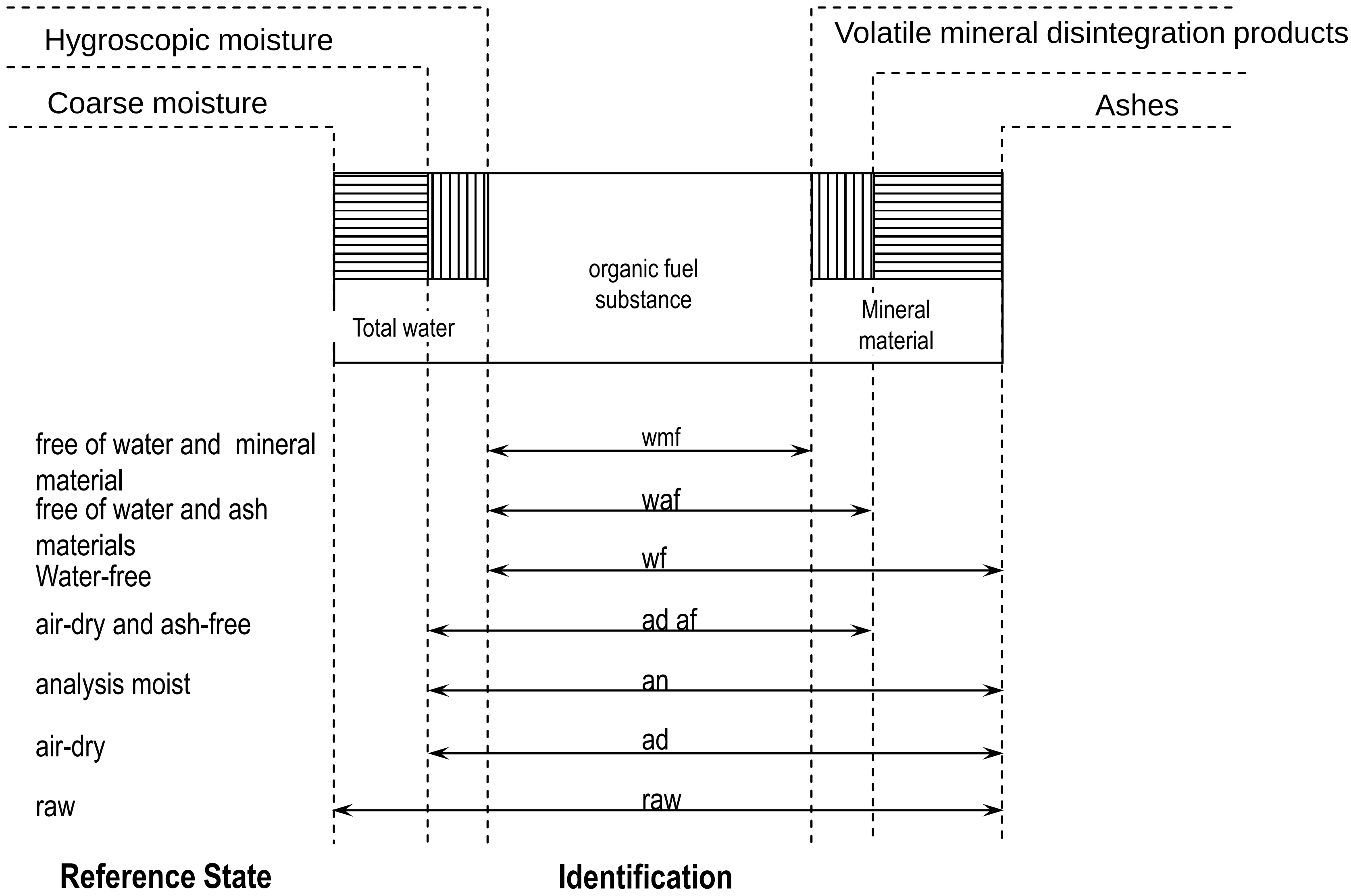


Reference States for the Caloric Value

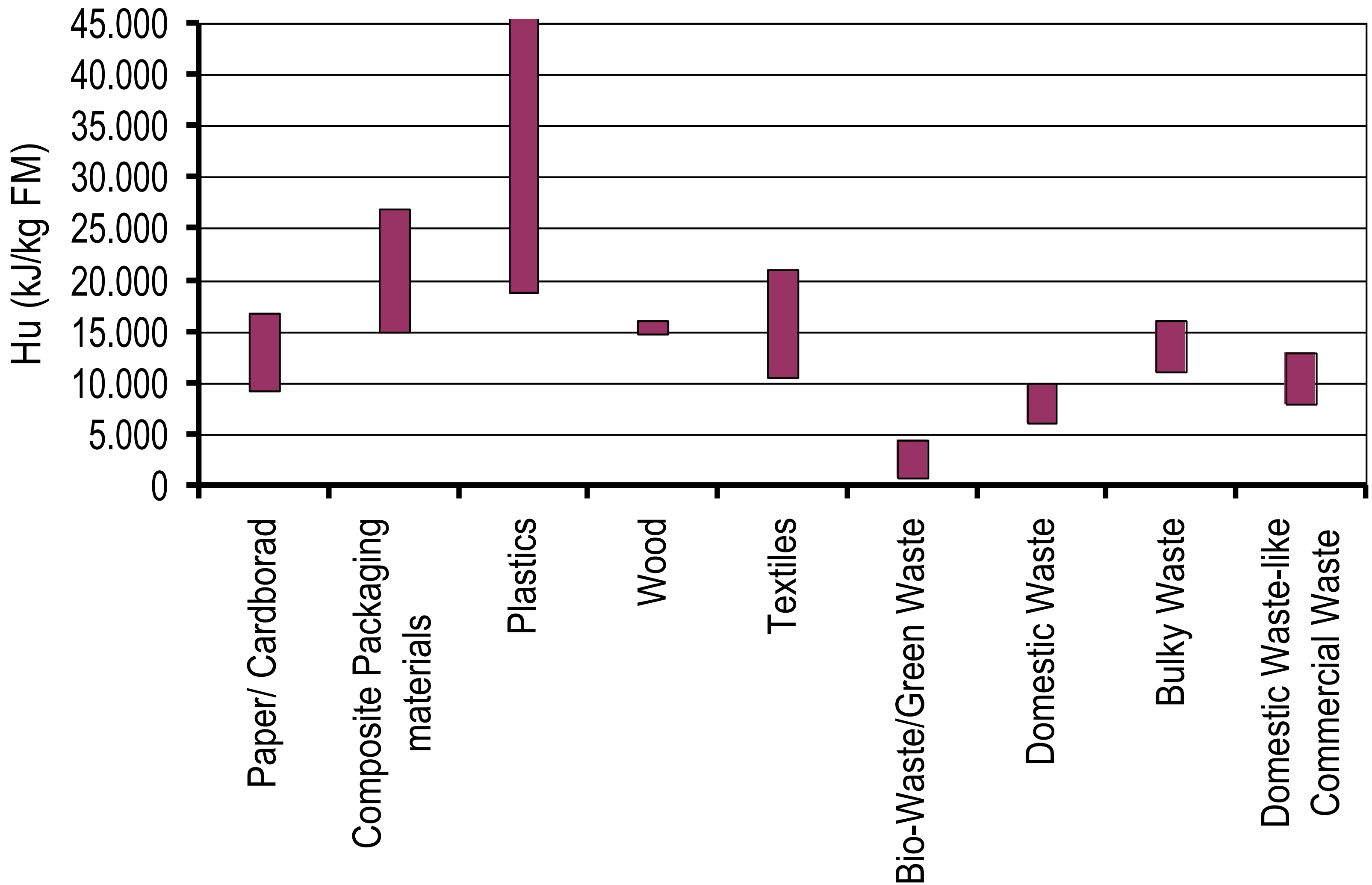
If the water amount released from the hydrogenous compounds during combustion is neglected, the following relations apply (cf. DIN 51700 and 51900):

given	requested: H_u (raw)	H_u (an)	H_u (wf)	H_u (waf)	H_u (wmf)
H_u (raw)	=	$[H_u(raw)+k*W] * \frac{100-w}{100-W} - k*w$	$[H_u(raw)+k*W] * \frac{100}{100-W}$	$[H_u(raw)+k*W] * \frac{100}{100-[W+A(roh)]}$	$[H_u(raw)+k*W] * \frac{100}{100-[W+f_M*A(roh)]}$
H_u (an)	$[H_u(an)+k*w] * \frac{100-W}{100-w} - k*W$	=	$[H_u(an)+k*w] * \frac{100}{100-w}$	$[H_u(an)+k*w] * \frac{100}{100-[W+A(an)]}$	$[H_u(an)+k*w] * \frac{100}{100-[W+f_M*A(an)]}$
H_u (wf)	$H_u(wf) * \frac{100-W}{100} - k*W$	$H_u(wf) * \frac{100-w}{100} - k*W$	=	$H_u(wf) * \frac{100}{100-A(wf)]}$	$H_u(wf) * \frac{100}{100-f_M*A(wf)]}$
H_u (waf)	$H_u(waf) * \frac{100-[W+A(roh)]}{100} - k*W$	$H_u(waf) * \frac{100-[W+A(an)]}{100} - k*W$	$H_u(waf) * \frac{100-A(wf)}{100}$	=	$H_u(waf) * \frac{100-A(wf)}{100-f_M*A(wf)]}$
H_u (wmf)	$H_u(wmf) * \frac{100-[W+f_M*A(roh)]}{100} - k*W$	$H_u(wmf) * \frac{100-[W+f_M*A(an)]}{100} - k*W$	$H_u(wmf) * \frac{100-f_M*A(wf)}{100}$	$H_u(wmf) * \frac{100-f_M*A(wf)}{100-A(wf)}$	=

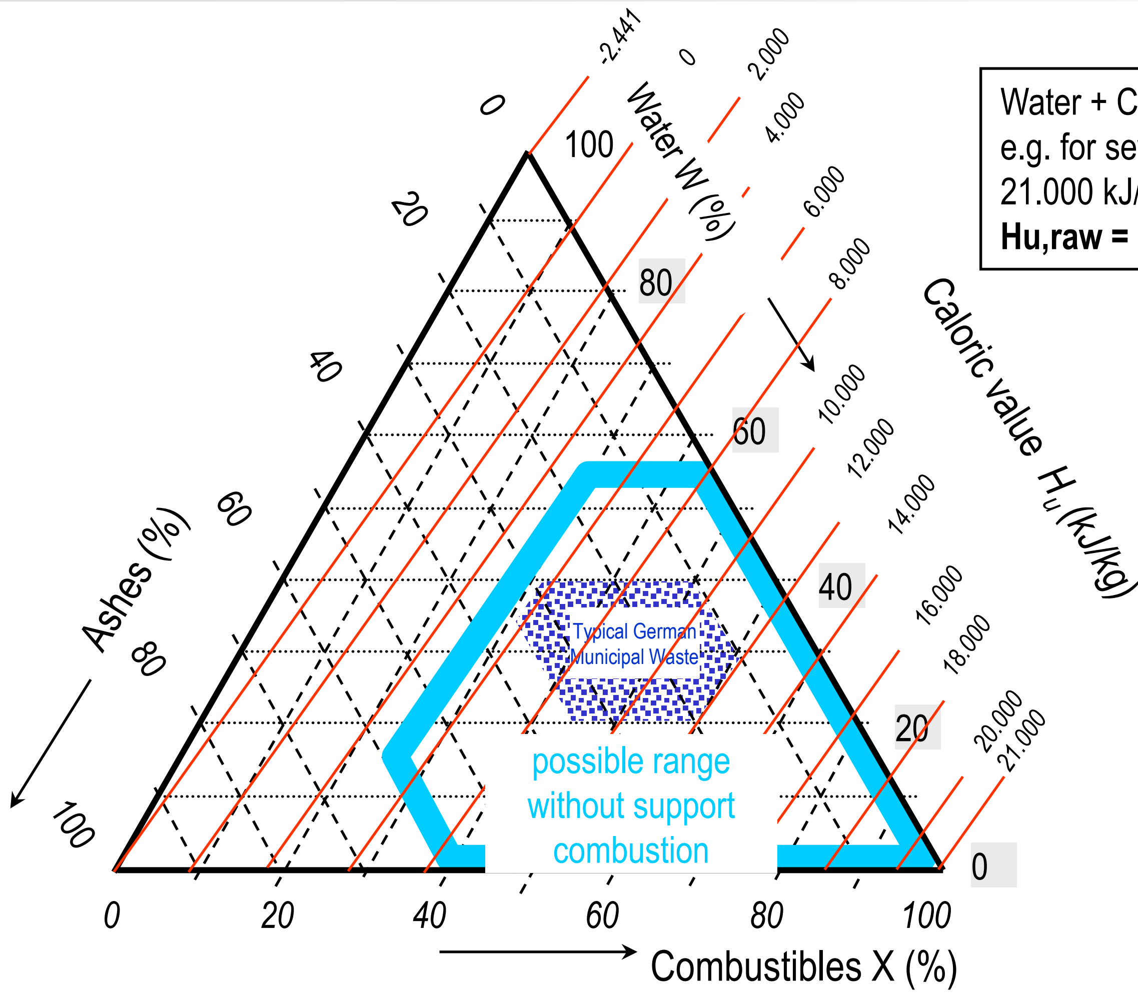
Reference States for the Heating Value



Caloric Values H_u of Various Waste Types and Fractions



Combustion Triangle for Municipal Waste



Water + Combustibles + Ashes = 100 %
e.g. for sewage sludge: H_U of the oDM = ca. 21.000 kJ/kg
Hu,raw = 210*X(%) - 24,41*W(%)

For ash contents = 0, the following applies

x*21000 - (1-x)* 2441 = Hu
x*(21000+2441) -2441 = Hu
x= (Hu+2441)/23441

Hu (kJ/kg)	X
0	0,104134
2000	0,189454
4000	0,274775
6000	0,360096
8000	0,445416
10000	0,530737
12000	0,616057
14000	0,701378
16000	0,786699
18000	0,872019
20000	0,957340

Domestic waste only — $H_{u,raw}$ = ca. 7.000 to 9.000 kJ/kg
mixed residual municipal waste — $H_{u,raw}$ = ca. 8.000 to 11.000 kJ/kg
(for total dimensioning: — $H_{u,raw}$ = ca. 5.000 to 12.000 kJ/kg)
fuel from waste (RDF) — $H_{u,raw}$ = ca. 11.000 to 20.000 kJ/kg

WC, DOS, IL and H_u in Domestic Waste

	Mass ratio [%]	Water contents [%]	WC ratio [%]	Ignition loss [%]	IL ratio [%]	DOS [%]	DOS constribution [%]	Heating value Hu [kJ/kg FS]	Caloric value [kJ/kg HM]
Fine waste	20 %	40 %	8 %	60 %	12,0 %	50 %	10,0 %	6.944	1.389
Stone, ceramics	2 %	5 %	0 %	2 %	0,0 %	0 %	0,0 %	296	6
Wood	1 %	25 %	0 %	90 %	0,9 %	50 %	0,5 %	14.240	142
Textiles/Leather/Rubber	2 %	15 %	0 %	85 %	1,7 %	20 %	0,4 %	15.529	311
Vegetable material	40 %	60 %	24 %	80 %	32,0 %	70 %	28,0 %	5.575	2.230
Metals	3 %	0 %	0 %	0 %	0,0 %	0 %	0,0 %	0	0
Glass	5 %	0 %	0 %	0 %	0,0 %	0 %	0,0 %	0	0
Plastics	4 %	8 %	0 %	95 %	3,8 %	0 %	0,0 %	25.000	1.000
Paper, Cardboard	10 %	20 %	2 %	90 %	9,0 %	70 %	7,0 %	15.352	1.535
Diapers	9 %	50 %	5 %	90 %	8,1 %	75 %	6,8 %	8.680	781
Composite materials	4 %	10 %	0 %	75 %	3,0 %	40 %	1,6 %	14.606	584
Average DW/GW	100 %		40 %		71 %		54 %		7.978

DOS = degradable organic substance

Model Calculation for Sewage Sludge

- Sewage sludge before dewatering 3,5 % dry matter
- after dewatering: of 1000 g moist weight 300 g dry
  WC_{moist} =
  cf. WC_{dr} in soil engineering =
- after technical drying, of 1000 g moist weight 800 g are dry
  WC =
- IL (% of the dry matter) = $100 \cdot (m_b - m_c) / (m_b - m_a)$ / =
  - m_a Mass of the empty crucible in g
    = 50 g
  - m_b Mass of the crucible with the dry matter in g
    = 70 g
  - m_c Mass of the crucible with the annealed dry matter in g

    = 60 g
- Heating value from calorimeter test H_u = 10.000 kJ / kg DM;
  calculation $H_{u,waf}$ =
  $H_{u,raw\ WC=20\%}$ =
  $H_{u,raw\ WC=70\%}$ =
  $H_{u,raw\ WC=96,5\%}$ =
- Necessary dewatering degree for automatic combustion

Reference States for the Caloric Value

If the water amount released from the hydrogenous compounds during combustion is neglected, the following relations apply (cf. DIN 51700 and 51900):

given	requested: H_u (raw)	H_u (an)	H_u (wf)	H_u (waf)	H_u (wmf)
H_u (raw)	=	$[H_u(raw)+k*W] * \frac{100-w}{100-W} - k*w$	$[H_u(raw)+k*W] * \frac{100}{100-W}$	$[H_u(raw)+k*W] * \frac{100}{100-[W+A(roh)]}$	$[H_u(raw)+k*W] * \frac{100}{100-[W+f_M*A(roh)]}$
H_u (an)	$[H_u(an)+k*w] * \frac{100-W}{100-w} - k*W$	=	$[H_u(an)+k*w] * \frac{100}{100-w}$	$[H_u(an)+k*w] * \frac{100}{100-[W+A(an)]}$	$[H_u(an)+k*w] * \frac{100}{100-[W+f_M*A(an)]}$
H_u (wf)	$H_u(wf) * \frac{100-W}{100} - k*W$	$H_u(wf) * \frac{100-w}{100} - k*W$	=	$H_u(wf) * \frac{100}{100-A(wf)]}$	$H_u(wf) * \frac{100}{100-f_M*A(wf)]}$
H_u (waf)	$H_u(waf) * \frac{100-[W+A(roh)]}{100} - k*W$	$H_u(waf) * \frac{100-[W+A(an)]}{100} - k*W$	$H_u(waf) * \frac{100-A(wf)}{100}$	=	$H_u(waf) * \frac{100-A(wf)}{100-f_M*A(wf)]}$
H_u (wmf)	$H_u(wmf) * \frac{100-[W+f_M*A(roh)]}{100} - k*W$	$H_u(wmf) * \frac{100-[W+f_M*A(an)]}{100} - k*W$	$H_u(wmf) * \frac{100-f_M*A(wf)}{100}$	$H_u(wmf) * \frac{100-f_M*A(wf)}{100-A(wf)}$	=

Model Calculation for Sewage Sludge

- After dewatering: of 1000 g moist weight 300 g dry residues
  WC_{moist} = =
  cf. WC_{dr} in soil engineering = =
- After technical drying: of 1000 g moist weight, 800 g are dry
  WC = =
- **IL** (% of the dry matter) = $100 \cdot (m_b - m_c) / (m_b - m_a)$ /
  = =
  - m_a Mass of the empty crucible in g = 50 g
  - m_b Mass of the crucible with the dry matter in g = 70 g
  - m_c Mass of the crucible with the annealed dry matter in g = 60 g
- Heating value from calorimeter test H_u = 10.000 kJ / kg DM;
  calculated $H_{u,waf}$ = = kJ/ kg oDM
  $H_{u,raw\ WC=70\%}$ = = 3000-1709 =
  $H_{u,raw\ WC=20\%}$ = =
  $H_{u,raw\ WC=96,5\%}$ = =
- necessary WC for 5000 kJ/kg =

Model Calculation for Sewage Sludge

- After dewatering: of 1000 g moist weight 300 g dry residues
  WC_{moist} = (1000 - 300) / 1000 = 700 / 1000 = 70%
  cf. WC_{dr} in soil engineering = 700 / 300 = 233%
- After technical drying: of 1000 g moist weight, 800 g are dry
  WC = (1000 - 800) / 1000 = 200 / 1000 = 20%
- **IL** (% of the dry matter) = $100 \cdot (m_b - m_c) / (m_b - m_a)$ /
  = $100 \cdot (70-60) / (70 - 50) = 100 \cdot 10 / 20$ = 50%
  - m_a Mass of the empty crucible in g = 50 g
  - m_b Mass of the crucible with the dry matter in g = 70 g
  - m_c Mass of the crucible with the annealed dry matter in g = 60 g
- Heating value from calorimeter test H_u = 10.000 kJ / kg DM;
  calculated $H_{u,waf}$ = 10.000 · 100 / (100-50) = 20.000 kJ/ kg oDM
  $H_{u,raw\ WC=70\%}$ = 10.000 · (100-70) / 100 - 24,41 · 70 = 3000-1709 = 1291
  $H_{u,raw\ WC=20\%}$ = 8.000 - 488 = 7512
  $H_{u,raw\ WC=96,5\%}$ = 350 - 2356 = 2006
- necessary WC for 5000 kJ/kg = 40,2 %

Parameter	n	$\bar{x}$*)	$\tilde{x}$*)	v*)	n	$\bar{x}$*)	$\tilde{x}$*)	v*)	n	$\bar{x}$*)	$\tilde{x}$*)
	Fine fraction				**Middle fraction**				**Electronic scrap**		
Moisture	25	28,7	27,8	0,18	25	49,7	51,2	0,16	16	0,7	0,4
Caloric value	24	5.448	5.230	0,30	24	14.886	14.936	0,11	16	23.093	21.4
TOC[1]	25	15,0	14,6	0,27	19	38,7	39,2	0,12	12	49,6	52,5
Cl[1]	25	0,67	0,63	0,38	25	0,83	0,80	0,25	16	3,58	3,18
S[1]	25	0,87	0,69	0,58	25	0,56	0,36	0,60	16	0,26	0,22
Cd[3]	25	2,42	2,00	0,58	25	4,25	2,00	1,28	16	228,82	56,4
Cr[3]	25	279	122	1,75	25	89	53	0,87	16	728	549
Cu[3]	25	223	120	1,21	25	139	61	1,47	16	20.459	16.0
Hg[3]	25	0,39	0,12	3,27	25	0,11	0,08	1,10	16	1,69	0,15
Ni[3]	25	26	23	0,44	25	17	14	0,58	16	1.544	488
Pb[3]	25	131	105	0,72	25	83	57	0,78	16	2.713	2.61
Zn[3]	25	373	359	0,39	25	382	253	0,95	16	4.448	3.06
PAK[4]	25	19.992	6.196	2,35	25	2.546	1.892	0,90	16	9.740	4.69
PCB[4]	21	121,9	55,0	1,47	19	121,3	64,6	1,10	10	186,1	169,
PCDD/F[5]	20	17,6	9,5	1,58	20	17,7	3,3	3,59	10	4,2	3,0
PCPh[4]	15	165,2	70,4	1,38	15	117,6	64,1	1,22	12	196,5	102,
	Glass				**Wood**				**Hygiene products**		
Moisture	16	1,1	0,6	1,15	16	13,9	12,4	0,42	16	61,8	62,4
Caloric value	–	n. b.	n. b.	n. b.	16	18.215	17.745	0,10	16	19.942	19.5
TOC[1]	15	0,6	0,5	0,46	13	46,0	46,4	0,05	13	46,3	46,6
Cl[1]	15	0,06	0,03	0,95	16	0,07	0,07	0,51	16	0,39	0,37
S[1]	15	0,05	0,04	0,64	16	0,07	0,06	0,35	16	0,13	0,13
Cd[3]	15	2,63	3,00	0,33	16	2,76	2,60	0,65	16	2,53	2,75
Cr[3]	15	372	396	0,36	16	13	11	0,95	16	21	20
Cu[3]	15	14	12	0,40	16	34	10	2,46	16	24	23
Hg[3]	12	0,01	< 0,01	1,15	15	0,51	0,05	3,24	13	0,10	0,07
Ni[3]	15	16	12	0,78	16	7	7	0,54	16	9	10
Pb[3]	15	429	143	2,50	16	36	33	0,74	16	11	8
Zn[3]	15	103	61	1,15	16	162	79	1,26	16	281	194
PAK[4]	–	n. b.	n. b.	n. b.	16	7.162	1.107	3,12	15	864	545
PCB[4]	–	n. b.	n. b.	n. b.	9	446,0	42,6	2,27	10	29,6	18,3
PCDD/F[5]	–	n. b.	n. b.	n. b.	10	20,3	8,9	1,71	10	0,6	0,4
PCPh[4]	–	n. b.	n. b.	n. b.	12	1.727,5	1.211,4	0,93	13	71,2	37,6
	Inert materials				**Plastic packaging materials/foils**				**Leather/Rubber/Cork**		
Moisture	16	2,1	1,8	0,45	17	16,8	15,2	0,31	16	6,0	6,3
Caloric value	–	n. b.	n. b.	n. b.	17	36.145	36.268	0,03	15	25.851	24.6
TOC[1]	16	1,0	0,6	0,90	17	73,0	73,8	0,08	14	55,9	55,1
Cl[1]	16	0,14	0,03	1,78	16	0,28	0,26	0,50	12	2,39	2,27
S[1]	16	1,76	0,54	2,07	16	0,18	0,16	0,45	12	1,05	0,85
Cd[3]	16	32,61	3,50	1,83	16	3,08	3,00	0,41	12	18,47	10,4
Cr[3]	16	197	125	0,84	16	89	45	1,36	12	7.885	5.85
Cu[3]	16	51	28	1,16	16	90	79	0,71	12	192	77
Hg[3]	15	0,03	0,01	1,22	17	0,08	0,04	1,83	16	1,63	0,16
Ni[3]	16	36	28	0,73	16	20	11	1,35	12	31	15
Pb[3]	16	1.402	1.221	0,97	16	129	64	1,06	12	180	88
Zn[3]	16	916	752	0,61	16	948	881	0,53	12	5.155	4.14
PAK[4]	–	n. b.	n. b.	n. b.	17	1.674	1.370	0,66	15	24.120	12.0
PCB[4]	–	n. b.	n. b.	n. b.	10	113,7	87,2	0,91	10	237,5	292,
PCDD/F[5]	–	n. b.	n. b.	n. b.	10	1,6	0,7	1,83	12	81,5	10,3
PCPh[4]	–	n. b.	n. b.	n. b.	17	104,1	51,0	1,45	12	6.595,2	1.19

Units 1) g/(100 g) 2) kJ/kg 3) mg/kg 4) µg/kg 5) ng I-TEQ/kg

Parameter	n	$\bar{x}$*)	$\tilde{x}$*)	v*)	n	$\bar{x}$*)	$\tilde{x}$*)	v*)	n	$\bar{x}$*)	$\tilde{x}$*)	v*)
	Organic waste				**Paper/Cardboard/Carton**				**Renovation waste**			
Moisture	16	61,3	61,2	0,09	16	21,9	20,4	0,28	13	5,7	5,8	0,50
Caloric value	16	17.494	17.209	0,08	16	14.160	14.259	0,06	12	19.527	20.054	0,16
TOC[1]	14	43,0	42,7	0,07	13	37,4	36,8	0,07	13	44,9	44,5	0,14
Cl[1]	16	0,86	0,86	0,12	16	0,15	0,14	0,48	13	0,90	0,44	1,44
S[1]	16	0,22	0,21	0,13	16	0,12	0,11	0,26	13	0,61	0,50	0,66
Cd[3]	16	2,79	2,85	0,60	16	2,31	3,00	0,41	13	24,46	2,40	2,83
Cr[3]	16	20	17	0,71	16	30	20	0,91	13	87	48	1,09
Cu[3]	16	33	17	1,33	16	54	51	0,26	13	75	19	1,87
Hg[3]	16	0,04	0,02	1,85	15	0,06	0,03	1,78	13	0,29	0,05	2,21
Ni[3]	16	8	6	0,39	16	10	10	0,52	13	22	12	0,99
Pb[3]	16	15	8	1,47	16	14	12	0,49	13	322	72	1,97
Zn[3]	16	60	54	0,34	16	139	57	1,15	13	1.686	1.044	0,87
PAK[4]	15	602	316	1,09	16	1.185	910	0,76	13	5.204	3.950	0,93
PCB[4]	7	31,7	19,0	1,11	11	88,2	44,7	1,38	10	264,7	136,2	10,4
PCDD/F[5]	10	11,3	0,4	3,00	10	1,5	1,2	1,08	10	17,4	5,3	1,35
PCPh[4]	9	55,1	22,9	1,10	12	202,1	144,9	0,86	9	1.022,3	599,2	1,19
	Shoes				**Other plastics**				**Other composites**			
Moisture	16	5,2	5,4	0,23	16	5,3	4,9	0,75	16	7,4	7,1	0,37
Caloric value	16	23.445	23.387	0,05	16	32.305	31.797	0,11	16	20.978	21.176	0,10
TOC[1]	13	51,4	51,1	0,09	14	68,9	68,4	0,13	12	48,4	48,4	0,12
Cl[1]	15	2,40	1,85	0,71	16	3,48	2,33	1,12	16	1,31	1,29	0,55
S[1]	15	0,66	0,63	0,27	16	0,15	0,13	0,43	16	0,59	0,37	1,72
Cd[3]	15	12,88	8,70	0,98	16	76,17	43,00	1,11	16	26,55	20,90	0,61
Cr[3]	15	5.992	5.490	0,42	16	334	86	2,05	16	2.749	1.567	1,05
Cu[3]	15	57	45	0,64	16	101	50	1,43	16	834	150	2,53
Hg[3]	16	0,18	0,10	1,63	16	0,08	0,04	2,00	16	0,64	0,20	2,03
Ni[3]	15	13	10	0,85	16	18	15	0,66	16	148	24	2,78
Pb[3]	15	324	217	1,15	16	473	215	1,51	16	638	482	0,79
Zn[3]	15	1.819	1.722	0,45	16	626	449	0,92	16	2.289	1.351	1,22
PAK[4]	16	8.458	6.958	0,84	16	2.659	1.840	1,00	15	8.986	3.188	1,98
PCB[4]	13	236,8	228,5	0,74	12	751,2	131,2	1,66	10	255,6	143,6	0,82
PCDD/F[5]	14	24,8	6,4	2,28	13	4,2	3,4	1,31	10	14,9	9,5	1,23
PCPh[4]	12	2.957,4	1.059,3	1,51	9	112,0	100,4	0,75	12	1.243,7	533,2	1,46
	Vacuum cleaner bags				**Textiles**				**Composite packaging materials**			
Moisture	16	11,1	9,9	0,26	16	14,3	14,1	0,33	16	19,0	19,0	0,23
Caloric value	16	13.309	13.230	0,14	16	18.851	18.719	0,06	16	22.072	22.086	0,06
TOC[1]	16	35,1	36,2	0,14	14	46,5	47,1	0,07	14	47,8	47,9	0,07
Cl[1]	16	1,24	1,10	0,63	16	0,12	0,10	0,47	16	0,35	0,27	0,67
S[1]	16	1,29	1,31	0,26	16	0,28	0,23	0,46	16	0,12	0,11	0,25
Cd[3]	16	3,89	2,95	1,19	16	2,44	2,75	0,30	16	3,02	3,00	0,27
Cr[3]	16	183	116	1,45	16	118	75	0,82	16	28	20	1,40
Cu[3]	16	119	102	0,52	16	57	47	0,57	16	101	93	0,42
Hg[3]	16	0,71	0,26	2,49	16	0,66	0,05	3,48	16	0,05	0,02	1,76
Ni[3]	16	28	28	0,43	16	12	10	0,54	16	13	10	0,77
Pb[3]	16	154	77	1,83	16	100	15	2,72	16	11	9	0,67
Zn[3]	16	684	637	0,43	16	256	216	0,71	16	95	80	0,56
PAK[4]	16	2.360	1.514	0,90	16	4.101	1.521	2,26	16	828	557	1,22
PCB[4]	11	282,0	188,7	1,01	10	84,3	67,9	0,59	11	89,3	32,9	1,92
PCDD/F[5]	11	24,9	9,7	1,16	10	8,6	6,1	1,25	9	2,0	0,7	1,94
PCPh[4]	13	942,9	602,5	0,80	12	237,6	245,2	0,54	13	153,8	98,5	1,31

Units 1) g/(100 g) 2) kJ/kg 3) mg/kg 4) µg/kg 5) ng I-TEQ/kg