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Development and application of waste factors - an overview

Prepared by:
Lutz Mertins, ABAG-itm GmbH
Carles Vinolas, Anna Bargallo, Gisela Sommer & Josep Renau,
Generalitat de Catalunya, Junta de Residus

Project manager:
Anton Azkona
European Environment Agency

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European Environment Agency
Kongens Nytorv 6
DK-1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.eu.int

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Executive summary

Background and objective
Projections and scenarios on future waste generation and flow in the various EU Member States and regions rely mostly on data compiled by different institutions in the Member States or by Eurostat. Based on these data and on the expertise concerning generation, flow, and management of waste, factors can be derived to provide a broader basis for making more precise projections of future waste arising and assessing the impact of different scenarios.

The immediate objective of the report is to provide an overview on waste factors, their derivation and application and the experiences made, based on reports and literature available. The report has been prepared by the European Topic Centre on Waste (ETC/W) as part of the work programme of the European Environment Agency.

State of knowledge
The scope of the report focuses mainly on EU15 and is based on literature and reports published by the European Commission, Eurostat, European IPPC Bureau and by institutions (national EPAs, national statistic offices, national and regional waste management authorities, scientific institutions) in the different Member States.

In addition, literature and information about other substantial activities, in some cases outside the EU have been taken into account: e.g. United Nations Environmental Programme (UNEP), United Nations Department for Policy Co-ordination and Sustainable Development (UN-DPCSD), Organisation for Economic Co-operation (OECD) and Development, International Organisation for Standardisation (ISO) for , Environmental Protection Agency USA (EPA). The look outside the EU is indispensable in order to define the position of the EU in comparison to other industrialised zones in the world.

The review has led to the general conclusion that a great number of activities are presently being carried out in many institutions, thus providing valuable information on the development and application of waste factors. However, the results available show that comparability and transferability are limited:

- goals, contents, and outcome of the activities differ widely;
- there is a lack of standards (definitions, terminology, methodologies);
- activities are not co-ordinated;
- activities are influenced to a great extent by statistics, not necessarily by the point of view and interest of waste management or sustainable resource management;
- studies and reports published by public institutions are the main source, whilst the manifold experience and knowledge of industrial associations and companies in this field are more difficult to obtain;
- most studies are focused on the development of waste factors and its methodology aspect;
- experience gained by practical application of waste factors on the macro-economic level is still limited, and often raises more questions than it answers;
- practical application of waste factors at the technology level in enterprises, e.g. benchmarks, is quite common, but shows that the specific situation has to be considered.

Environmental Pressure Information System EPIS
EPIS is based on the methodology of conventional material flow balances: the input of material and energy into a system or process are considered equivalent to the accumulation and the output of products and other emissions (waste, wastewater, air emissions ...) as a result of the process within a defined period. With this conceptual framework EPIS fits easily into both the presently used system of sectional economical statistics and the national accounts.

The model links statistics on economic activity and consumption through the pressures they produce to data on the state and impact on the environment. EPIS will contribute to the development of pressure indicators by providing data on material flow and emissions of selected harmful substances into air and water.

EPIS started in 1994 with a pilot phase involving France, Germany, Italy and the Netherlands. The present phase includes pilot projects in Austria, Finland, Norway, Spain and Sweden in which consistent data structures will be developed, linking economic statistics and process specific data. In addition, input-output data for specific processes will be developed.

European Integrated Pollution, Prevention and Control (IPPC) Bureau
The activities of the IPPC Bureau on best available techniques in different production sectors should also be considered. Based on Council Directive 96/61/EC the IPPC Bureau elaborates documents, which describe selected techniques and give information on

- consumption and emission levels achievable by using each technique;
- the costs and cross media issues associated with each technique; and
- the extent to which each technique is applicable to the range of installations requiring IPPC permits.

The IPPC Bureau has already published first results in (draft) documents on best available techniques, giving detailed information about the material flow in installations in these industrial sectors

Definitions and terminology
Environmental **factors** are in general related to an activity or source, e.g. describing emissions linked to an industrial process; using the DPSIR assessment framework they are related to the driving force. They are obtained by relating the quantity emitted to a specific product or source or activity. These factors are based on measured and/or calculated and/or estimated values.

Examples of waste factors are
- quantity of waste generated per inhabitant and year;
- quantity of paint sludge per car produced.

Definitions and terminology used in different reports are not consistent, which makes a comparison of the activities and their outcome almost impossible. For example:

- description of waste types: e.g. national waste code, European Waste Catalogue, other classifications;
- classification and description of material: e.g. type of input material;
- definition and characterisation of industrial sector: e.g. NACE, national classification, others;
- definition and characterisation of process technology.

Also the **system** considered in the different studies is quite often not clearly specified. For example

- industrial sector: NACE, national code, others;
- process technology: primary production process only, or including secondary and ancillary processes, e.g. on-site recycling technology;
- type of material, e.g. raw material, initial products, and operational material on the input side; product, by-product, and waste on the output side.

According to goal and purpose different **reference units** are used in practice:

- production unit, e.g. foundry industry: 0.250 tonne of used sand per 1 tonne of product;
- monetary unit, e.g. 25 tonnes of waste per 1 million Euro product value;
- number of employees, e.g. 500 kg of waste per employee and year.

Many other reference units are used, thus aggravating the comparison of results.

The studies are based on different **data sources**, e.g. economic statistics, waste statistics, empirical data (measured data, waste declarations, inspection reports, company data), literature or practical knowledge.

The selection of data and data sources depends mainly on the level considered (EU, national, regional, process technology or enterprise level). Due to **lack of appropriate data** in many cases assumptions have been used. Another aspect which should be taken into account is the **timeliness of data**: most of the data is more than five years old and do not reflect the current situation.

The various aspects presented above hinder the comparability and the practical applicability of the results to a great extent. This can be illustrated by the following **example** from the foundry industry, as presented in four different studies[a]. In these studies different **databases** have been used (national economy statistics, national waste statistics, empirical data, literature). The **waste type** is merely described as 'used foundry sand', without any further specification. The **system** considered is described as 'foundry industry', in some cases without any information regarding process, sub-process, etc. Therefore, different values for the derived waste factors have been found:

Study	**A**	**B**	**C**	**D**
Waste Factor, kg used sand per tonne product	585 – 603	280 – 510	340 – 450	500 – 4.500

[a] The four examples are described in detail in Section III of this report.

Application of waste factors
Waste factors link waste generation with other – mainly economic – features. This is considered to be the main reason why public administration, political decision makers and industrial managers are interested to apply waste factors – each for its own specific purpose:

Interested Party	Application (Examples)	Data Source (Examples)
• public administration at regional level	• compare waste generation of different production sites	• statistics • inspection reports • waste declarations
• public administration at national level	• compare waste production in its own nation with others • develop trends / projections	• statistics
• public administration at EU/international level	• check if regulations and legal provisions are implemented consistently • develop trends and projections	• statistics (economy, waste)
• political decisionmaker	• set targets for regulations • check effectiveness of regulations • improve regulations	• statistics • expertise • specific literature
• management of production sites	• benchmarks (changes over time, efficiency of material resources and waste management)	• empirical data • literature/expertise • statistics
• management of production processes	• benchmarks (changes over time, efficiency of material resources and waste management)	• empirical data • literature/expertise • statistics
• planning of production sites	• implementation of state-of-the art (SoA) • improve licence procedures	• literature/expertise • SoA
• planning of waste treatment and disposal structure/facilities	• projections about future waste arising	• specific literature • statistics • expertise

Conclusions
Despite recent developments in statistics and additional information, there is still a lack of comprehensive data on waste generation and flow. Therefore, waste factors are needed:

- to improve illustration of waste generation and flow;
- to detect inconsistencies in implementation of EU waste regulations at national level;
- to control waste flow and to measure minimisation efforts.
- to improve the basis for projections and scenarios

The assessment of the state-of-knowledge available reveals the advantages and disadvantages of both the development and application of waste factors, at technology level, industrial process level, and macro-economic level. The report shows that the development of waste factors is a very complex and extensive undertaking. Despite the manifold activities on waste factors, it has to be realised that there is as yet no nationally and/or internationally accepted system or set of waste factors for environmentally sustainable development available. Only a few of the reviewed activities are suitable to meet the demand of authorities, institutions, and managers responsible for waste management and waste planning, as well as the needs of statisticians. There is still a lack of verified factors which limits the fields of their practical application for the time being. To overcome these limitations should be the main objective for extensive work in the near future. If successful, the potential of waste factors as a tool for estimating waste and assisting waste management can be fully achieved.

Further work on waste factors should take into account activities at European level, especially the Environmental Pressure Information System (EPIS), and the elaboration of reference documents on best available techniques in main industrial sectors (IPPC). Additionally, relevant activities undertaken by academic/research institutions should also be taken into account.

SECTION I

1. Background

Environmental indicators and factors help to describe the state of environment, emissions linked to human activities, and the influence of environmental quality on human and ecological health. They are mostly related to environmental policy fields, e.g. air pollution, ozone layer depletion, resource depletion, and waste. Some of the indicators and factors are easy to produce, while others are difficult to obtain due to lack of appropriate and reliable data and information.

Since the publication of the report of the world Commission on Environment and Development, 'Our Common Future' in 1987, and even with greater effort since the United Nations Conference on Environment and Development in 1992, policy-makers, scientists and analysts have been trying to capture the concept of sustainable development in statistics. The discussion is mainly focused on trends in production patterns[a], and consumption patterns[b], and ways to influence them towards sustainability. Environmental indicators and factors assist to improve sustainability and are essential tools for policy making.

In this context waste factors have become increasingly important for monitoring changes, showing trends, and developing projections in the volume and intensity of waste generation. Even though the material intensity (material required for constant economic output) has fallen in industrialised countries at nearly two percent per year since 1971[1], mainly due to more efficient technologies and structural changes, the amount of waste generated per capita in industrialised countries has grown considerably in the same period. This fact leads to the conclusion that political, technological, and structural changes are necessary:

- to decrease intensities of material use in production and consumption;
- to minimise the generation of waste;
- to reduce the negative environmental and health effects of resource use and waste treatment/disposal;
- to progressively dematerialise consumption (defined as a reduction of anthropogenic material flows, or as a reduction in per capita use of materials).

Economic statistics or measures such as GDP[c] do not include the generation, processing or movement of materials that have no economic value. On the other hand the existing waste statistics are often incomplete and the data is uncertain. Therefore, waste factors, which consider the available data and information on material flows, including waste, will be a valuable tool for political decision-makers, company management, and waste management authorities to monitor changes in waste generation, and to develop projections with the aim to prepare the ground for decisions directed at waste minimisation and to reduce the negative effects related to waste.

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[a] Production patterns are characterised by the use of key resources: energy, materials incl. waste, water, land

[b] Consumption patterns are characterised by e.g. mobility, consumer goods and services, buildings and housekeeping, food, and recreation

[c] Gross Domestic Product: total value of goods produced and services provided in a country in one year

Despite the great number of activities in this field – e.g. UNCSD, OECD, WBCSD, EU, Eurostat, authorities in the EU Member States and institutions in several other nations – the availability of reliable waste factors for both monitoring trends and developing projections is still limited. And there is very little experience yet gained from the practical application and use of waste factors.

With respect to EU waste management policy, waste factors may be able to support implementation of the 5th Environmental Action Programme[a]. Policy-makers including members of the European Parliament or the European Council need to consider the following aspects of source orientated waste management:

- consistent implementation of EU legislation;
- the amount and quality of waste generated in the EU should develop in a sound way, appropriate to the demands of 'sustainable development';
- EU must be ready to meet the challenge to produce less waste than other industrialised zones in the world;
- EU must show that economic growth and wealth do not necessarily mean an increase in the generation of waste.

In order to reply to these requirements the European Commission (EC), as the executive needs to be furnished with reliable background information. Up to now EC must rely mostly on data compiled by the different institutions in the Member States or by Eurostat. In many Member States current waste statistics do not give an accurate picture of the state of waste generation and management, since

- different classification systems and definitions have been used, thus the effective comparison of data between countries is limited;
- determination of historical trends is often hampered by on-going changes in waste definitions and classification systems[2];
- waste data quality is often uncertain;
- waste statistics are incomplete.

2. Objective and scope

The immediate objective of this Technical Report is to provide an overview on waste factors, their derivation and application and the experiences made, based on reports and literature available[3].

The scope focuses mainly on EU15 and is based on literature and reports published by the European Commission, Eurostat, European IPPC Bureau, and by institutions in the different Member States. In addition, literature and information about substantial activities in some cases outside the EU have been taken into account: e.g. United Nations Environment Programme (UNEP), United Nations Department for Policy Co-Ordination and Sustainable Development (UN-DPCSD), Organisation for Economic Co-Operation and Development (OECD), International Organisation for Standardisation (ISO), Environmental Protection Agency USA (EPA). The look outside the EU is indispensable in order to define the position of the EU in comparison to other industrialised zones in the world.

The report is divided into four sections:

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[a] See also: The Environmental Pressure Indices Project

Section I comprises

- a brief introduction to the subject, and the goal and scope of this report;
- a definition of waste factors;
- the main criteria for the development of waste factors and the different levels of application;
- the practical use of waste factors in the development of projections on future waste arising;
- the role of waste factors in EU waste policy towards sustainability;
- an overview of waste factors, their derivation, their practical application and the experiences made;
- conclusions, considering the interested parties, the level of application and the availability of waste factors; and
- recommendations and a proposal for further activities.

The examples described in section II supplement the explanations given in section I of the report. These examples can offer only a small excerpt of the great variety of studies and reports about waste factors. They illustrate the different approaches, the different methodologies used and the results gained.

Section III comprises a comparison of waste factors and their applicability in the foundry industry and the aluminium smelting industry. This comparison is based on a choice of studies carried out in different EU Member States.

In section IV the abbreviations used in this report are explained, and the literature considered and its sources are stated.

3. Definitions

3.1. Terminology

In genera, environmental factors are related to an activity or source, e.g. describing emissions linked to an industrial process and are using the DPSIR-assessment framework they are related to Driving force and pressure (fig. 1) obtained by relating the quantity emitted to a specific product or source or activity. These factors are based on measured and/or calculated and/or estimated values.

Emission factors are already well established in the description and assessment of emissions into air and water, where source oriented and activity based models are normally used, and the necessary data are already available. Emission factors are required for 'quick' risk assessments and environmental comparisons of processes, and are being used in economic comparisons as well.

The development of waste factors (e.g. quantity of waste generated per inhabitant, quantity of paint sludge per car produced) has so far been limited; partly because of lack of data, but also because 'traditional' waste management has been focused on pressure state and impact. The 'new' way towards sustainability calls for source oriented approaches: waste prevention and minimisation. Therefore data and information referring to industrial processes – being the source of waste – as well as methodologies for a systematic approach are needed.

They are the basis to create waste factors for the concise and comparable description of present and future waste generation.

Fig. 1: Waste factors within the DPSIR-assessment framework

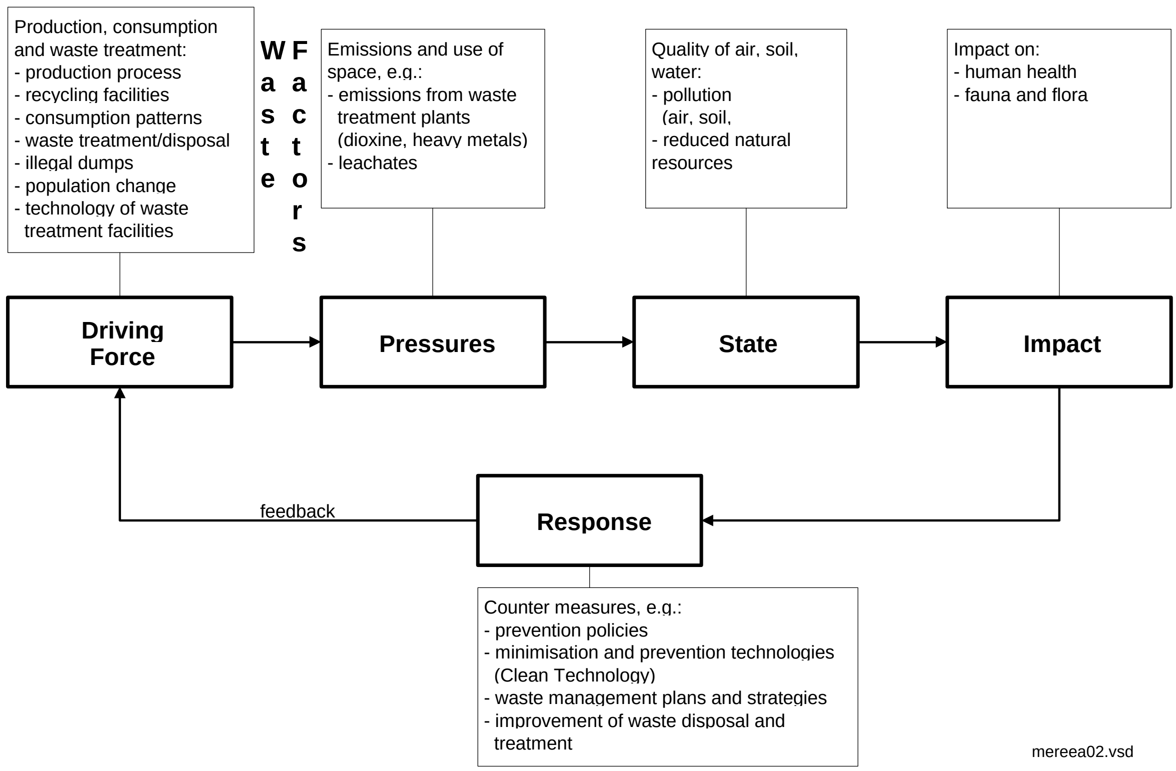
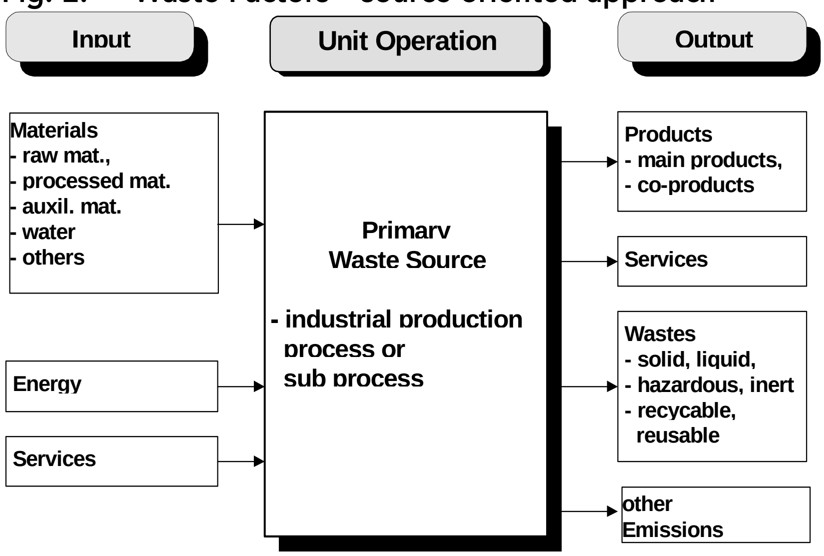


Fig. 2: Waste Factors – source oriented approach



3.2. Levels of application

Different 'customers' and thus levels of application have to be distinguished and treated separately. The report will have a view on the following levels:

- national or regional;
- industrial sectors;

- enterprises or production sites;
- technology, e.g. production process and sub processes.

The different characteristics, purposes, conclusions to be derived and the respective users or interested parties can be characterised as follows:
At **national level** waste factors as an informative tool may help to integrate environmental data with economic aspects, to describe for instance the quantity of waste per GDP unit or per inhabitant. Thus they might serve as a tool in order to compare efficiency of Member States or regions in minimising waste generation. The typical customer of these factors could be European Parliament or the European Commission, in order to check where financial resources could support national or regional attempts towards less waste. On the macro-economic level, waste factors will also supplement national or regional waste statistics and can therefore be used by statistics offices. They can be used to support the authorities in drawing up their national or regional waste management plans.

Waste factors at national level offer also the possibility to compare the waste situation between the EU and other industrialised regions in the world, with the aim to improve waste management. On the other hand waste factors might be useful to prove that economic growth does not necessarily mean an increase in the generation of waste.

In order to improve material efficiency at **industrial sector level** waste factors could consider the amount of waste as a whole (e.g. the entire electricity supply industry produces x tonnes of slag, filter dusts and other residues per year), or specified on type of fuel (e.g. coal-fired power plants produce y tonnes of slag, filter dusts and other residues per year) or related to the product (e.g. z tonnes of residues per MWh produced).

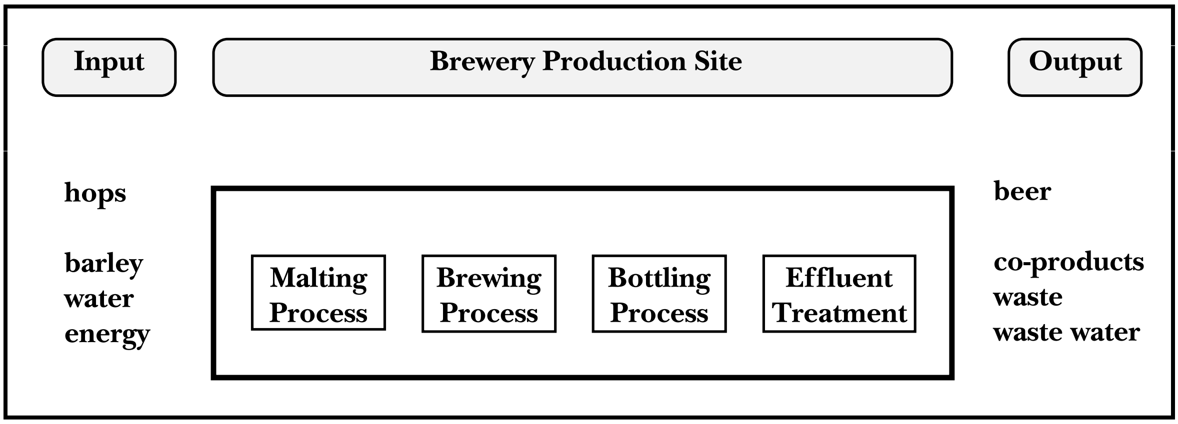
At **enterprise level** or **production site level** management faces more and more the challenge of implementing an Environmental Management and Auditing System and of paying more attention to the 'productivity' in waste. There is an increasing need for factors that can be applied as tools for the source oriented 'plan-do-check-act' approach in waste management, and which are therefore indispensable parts of an eco-controlling system.

At **technology level** it is necessary to distinguish between process level and sub-process level. The production process level, as generally defined by PRODCOM, considers the entire process, which is necessary to generate the product, e.g. electroplating process. The process can be divided into different sub-processes, e.g. degreasing, rinsing, galvanising etc. Waste factors are for instance the quantity of waste per product unit, e.g. 10 kg waste water sludge per 1000 kg net production of electroplated material; or 9 kg of paint sludge per car in a car manufacturing plant.

The supposed applicants of factors at technology level are on the one hand managers and technicians in charge of a production process and on the other hand public authorities, e.g. waste inspectorates, and authorities or institutions in charge of implementing Clean Technologies. The figures obtained can be compared to those found in technical literature based on standard technologies (benchmarks). The application shows, for example, if good housekeeping is applied or where potentials for waste minimising measures exist. These factors can be applied for planning and assessing activities to develop Clean Technologies and to support their implementation.

Example
The use of waste factors at different levels can illustrated by the following simplified example of a brewery process:

Fig. 3: Brewery process – simplified scheme



The **waste types** generated in a brewery process can be classified as follows (EWC nomenclature):

02 07 01	wastes from washing, cleaning and mechanical reduction of the raw material
02 07 04	materials unsuitable for consumption or processing (in this case: hop draff, malt draff, malt dust)
02 07 05	sludge from on-site effluent treatment

Revealing **waste factors** characterising the brewery process at different levels:

(a) **Industrial sector level:** The total amount of wastes mentioned above can be aggregated according to statistical requirements and compared to the quantity of product or financial turnover; thus the efficiency and waste relevance of the whole industrial sector can be compared with other sectors.
Interested party: economists, statisticians, actors in waste management;

(b) **Enterprise level:** The enterprise can compare its own waste factors (total quantity of waste per hectolitre of beer) with those revealed by the sector as a whole (a) or other individual breweries and thus conclude e.g. about better housekeeping efforts.
Interested party: management staff of the brewery, waste management authorities.

(c) **Individual technology level:** waste factors for the malting process (total quantity of waste 02 07 04 per tonnes of malt input) could be verified in order to decide about possibilities towards clean technology by comparing with waste factors disseminated e.g. in the literature.

Interested party: technical manager in charge of the malting process, waste management authorities.

3.3. Characteristic features of waste factors

To suit the demand of the 'consumers' or interested parties on the different levels of application, waste factors should fulfil the following criteria:

Table 1: Characteristic Features of Waste Factors

• **information, topicality**	provide both topical and representative picture of the waste situation of a source (production process, industrial sector, region, nation)
• **field of action**	point out or characterise problematic areas as well as possibilities and potentials of improvement
• **minimise expenses**	reduce the number of measurements and parameters normally required to give an 'exact' picture or description of the waste generation
• **simplification, communication**	be simple, easy to interpret and to communicate
• **projections, trends**	show trends over time and give basis for projections
• **evaluation**	be responsive to changes of the waste generation
• **assessment, benchmarking**	provide a basis for comparisons, e.g. between industrial sectors, technology alternatives, etc.
• **acknowledgement**	be based on common scientific standards or (international) consensus
• **quality, reliability**	be based on data and information of known quality, adequately documented and updated in regular intervals
• **methodology, framework**	be based on an acknowledged methodology/model and fit into a conceptual framework
• **relation to other sectors**	be linked to other sectors, e.g. economy and society

3.4. Waste factors and environmental management instruments

Within the broad use of the term environmental monitoring and assessment, there are specific environmental management instruments and procedures – e.g. Life Cycle Assessment (ISO 14041ff), and environmental auditing and management (EMAS, ISO 14001). These instruments describe and assess – according to their specific goals and orientation – the environmental relevance and impact of, for example, the different life stages of a product and of production measures and production sites. This includes aspects such as product definition, process design, process operation, material input, material output, end-use, re-use and recycling or disposal.

The development and application of waste factors should be seen in context with environmental management instruments. In fact, waste factors are a useful and demanded tool to be integrated into these instruments, as quantitative goals, targets, benchmarks etc. They help to define the environmental profile of products and processes, to assess environmental effects, and to communicate environmental statements when instruments like EMAS or LCA are applied.

4. Projections and scenarios applying waste factors

4.1. EU and national level

Taking into account the uncertainty of waste statistics, the forecast of waste amounts at EU and at national level is problematic, and until now little work has been done to analyse and explain future waste generation.

The EEA has requested the European Topic Centre on Waste to develop a methodology to project the future development of a number of selected waste streams in quantitative terms. The following description is partly quoted from the EEA technical report prepared by the ETC/W[4]:

Due to data limitations most of the studies link amounts of waste to economic activity t an aggregated level and assume proportionality between the amount of waste generated and the economic activity, i.e. when economic activity increases by 10%, the amount of waste increases by 10%. Therefore, he ratio between the amount of waste and the economic activity would be constant. However, this is not realistic due to the impact of the conditions and circumstances named in table 2. Therefore more data and information about the economic activities at a more detailed level are required, combined with a test whether historical data reveals proportionality between the amount of waste and the economic activity.

In general terms, it is assumed that there is a time dependent correlation between the amount of waste of a given category and some specific economic activity, i.e.

$$W^t_i = f\ (Y^t_i, ,T^t)$$

W^t_i = amount of waste of a given category in the period t;
Y^t_i= specific economic activity in time period t;
T^t = time

The relation f is specified as a log-linear form in an **estimated equation model**, i.e.

$$\log\ (W^t_i) = a_0 + a_1 * \log\ (Y^t_i) + a_2 * T^t$$

W^t_i, Y^t_i, , T^t = see above;
a_0, a_1, a_2 = coefficients (a_0 constant; a_1 proportionality coefficient between amount of waste and relevant economic activity; a_2 trend, almost equal to the annual %-change in the waste coefficient)

The data available is normally not sufficient to determine both a_1 and a_2. Therefore, for estimates it is assumed that $a_1 = 0$, i.e. the ratio between the amount of waste and the economic activity is assumed to follow an exponential trend, with a_2 estimated on historical observations:

$$\log\ (W^t_i / Y^t_i) = a_0 + a_2 * T^t$$

Since data availability does not always allow for estimates according to the above named equations, a_2 is assumed to be zero. This leads to the **constant coefficient model**, where e^{a2Tt} equals 1.0 and the waste coefficient equals a_0.

$$(W^t_i / Y^t_i) = a_0 * e^{a2Tt}$$

Assuming that a_2 = 0.0 the model is reduced to the 'constant coefficient' model, except for a_0 being estimated and therefore equal to the average waste coefficient over the estimated period.

With the 'estimated equation' model the economic model is used to generate data on waste generation for past years. These data are then compared with actual reported data for these years. If there is a good correlation between the historical data predicted by the model and actual reported historical data then the 'estimated equation' model can reasonably be used to make projections into the future.
Where the correlation is of poor quality, the 'constant coefficient' approach is considered more suitable.

The above approaches have been developed and tested for municipal waste/household waste, paper and cardboard waste and glass waste.

4.2. Production process level

In many companies the application of waste factors is quite common. In the context of environmental instruments, e.g. EMAS, ISO 14001, and ISO 14040, waste factors are needed to describe, plan, and optimise the material flow and the generation of waste at production or enterprise level. Waste factors are a necessary tool to set targets, to control, and to improve the production process, thus reducing the amount of waste generated, thereby minimising the environmental impact, and of major interest to the company – reducing costs.

While enterprises become more and more acquainted with environmental indicators as a useful internal tool, it has to be acknowledged that the application of waste factors as benchmarks/targets for production processes in general, or for industrial production sectors, is still problematic. In many cases industrial associations claim that the production processes applied in a specific industrial sector differ widely among individual manufacturers, and cannot be 'standardised'. Despite this fact it should be acknowledged by all stakeholders that waste factors – as well as other environmental factors – are a valuable tool to assist in the implementation of BAT and to set minimisation targets in voluntary agreements for a specified industrial sector[a] .

4.3. General conditions and circumstances of waste generation

The quantity of waste generated in a particular region or by a specific source is influenced by a great variety of conditions and circumstances (see table below). They are interconnected and affect each other. Their impact, i.e. their influence on the quantity of waste generated, depends mainly on:

- the political, economical and technical conditions;

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[a] Example: Waste factors have been successfully used in the voluntary agreement between Land Baden-Württemberg, Germany and the foundry industry to set waste minimisation targets for this specific industrial sector.

- the different interests and goals of the major stakeholders (producer, consumer, etc.);
- the level (macro-economic, production sector, enterprise, technology).

Table 2: Examples of conditions and circumstances influencing the waste generated in the manufacturing industry

general environmental policy	environmental goals (sustainable development); public demand; consumption patterns; environmental pressure groups; etc.
legal instruments	regulations/laws (production process, additive environment measures, pre-treatment, recycling, disposal, transfrontier shipment, bans, ...); classification/definition and declaration of waste; etc.
economic instruments	levies/taxes; disposal fees; recycling fees; implementation cost of clean technology; etc.
persuasive instruments	voluntary agreements; information availability (minimisation, disposal); promotion/support of innovative technology; etc.
enforcement/ control	control of emissions, of waste flows, of declaration (production source, treatment plants, ...); etc.
production process	design/operation/maintenance of technology used; state-of-the-art; material input; operation costs; investment costs; investment cycles; etc.
product	design of product; material input; material costs; use; durability; easy to repair; etc.
additive environment protection measures	end-of-pipe measures (waste water and air emission treatment; pre-treatment of waste); etc.
waste prevention	minimisation technology; environmental management; material substitution; pre-treatment; production and product design; etc.
recovery (recycling/re-use)	infrastructure; plants/techniques (availability, capacity,...); ownership; costs; etc.
disposal	infrastructure; plants/techniques (availability, capacity,...); ownership; costs; etc.
logistic/services	waste collection system (techniques/ownership/ management); infrastructure; sorting/pre-treatment; etc.
others	consumer/client demand; marketing; market conditions/ competition; EMAS/ISO 14001; neighbourhood complaints; etc.

4.4. The role of waste factors in the EU policy and strategy 'towards sustainability'

Making assessments, predictions and decisions based on waste factors require that these factors correspond to the EU waste policy and must be the result of reliable data. Thus sources and quantities of waste must be clearly defined and comparable. This in turn requires

- a common and unique understanding of waste sources and waste types and
- an established network of reporting requirements.

According to Framework Directive 75/442/EEC as amended by Directive 91/156/EEC, Member States shall take appropriate measures to encourage prevention or reduction of waste generation and its harmfulness[5]. In addition, Member States are asked to draw up waste management plans relating in particular to the type, quantity and source of waste to be recovered or disposed of. In order to achieve this task, waste factors are essential tools in prioritising targets and policy actions and support the activities as listed in the Fifth EU Environmental Action Programme[6], focusing on sustainability, which means

- to maintain the overall quality of life;
- to maintain continuing access to natural resources;
- to avoid lasting environmental damage;
- to consider as sustainable a development which meets the needs of the present without compromising the ability of future generations to meet their own needs.

These targets can only be met by involving all those policy areas causing environmental deterioration. Consequently, industrial waste minimisation and management with its strategic guidelines

1. Prevention
2. Recovery
3. Improving disposal conditions

is one of the major issues of the Fifth Action Programme. These priorities are further underlined by the Community Strategy of Waste Management COM(96)399[7].

In this respect, waste factors would be a valuable tool to measure and assess waste generation and treatment, to develop scenarios, goals and technologies for minimisation of waste at its source, and to set up the necessary legal framework and initiatives in the EU Member States.

5. Waste factors – activities, experiences, results

5.1. General remarks

There is a great number and variety of both projects and studies in which the environmental impact of production processes as well as waste generation, disposal and recycling processes have been described and assessed. Different systematic approaches have been used, with waste factors and indicators related to input materials, product quantities or product values, thus making process alternatives comparable.

The contents of the studies and reports vary to a great extent, according to the goals set:

- intended field and level of application;
- purpose: description of present conditions, making projections, assessment of performances, etc.;
- methodology / model (system boundaries, framework, etc.);
- customer;
- data and information/input requirements.

The different approaches of the projects and studies are described in this chapter. The description is supplemented in **section II** of this report by examples, which represent different approaches and methodologies.

5.2. Waste factors at national level and industrial sector level

Examples available on the derivation and application of waste factors at national level or at industrial sector level differ widely. Besides the already mentioned studies, further reports and studies have been considered for this report[8] [9] [10] [11] [12] [13] [14] [15] [16].

Some reports feature rather simplified models, closely related to the unit operation models used at technology level (fig. 2). Based, for example, on data from production statistics and waste statistics they allow

- comparison of the waste generation in different enterprises within a specified industrial sector, region or nation;
- comparison of the waste generation between different industrial sectors, regions or nations;
- chronological comparison of the waste generation in a specified industrial sector, region or nation.

An example for applying national level waste factors could provide for the estimation of quantities of waste generated even if statistical data gathered is not reliable ('fill-in-the-gap-method'):

Arbitrarily for secondary steel smelting the following waste factors are given:

Slag: 100 kg per metric tonne of steel produced
Filter dust: 10 kg per metric tonne of steel produced

In the region *XXX* we know that 600 000 tonnes of steel are produced but only 6 000 tonnes of waste (slags and filter dust) are reported. The missing 60 000 tonnes give reason for further investigation. The result might be – in this example – that in region *XXX* the 60 000 tonnes of slags have been considered as a by-product, since the slags have been used as substitute construction material. Therefore only the filter dust (6 000 metric tonnes) were listed in the waste statistic. On the contrary, in the reference region the slags have been considered as waste for recovery, and used for the same purpose as substitute construction material. This would mean that a significantly inconsistent interpretation of the EU Regulation had been explained.

Most activities related to waste factors at national and industrial sector levels are carried out by national statistics bureaus. The following examples should give some indication of the development and the experience made:

Statistical method
The Statistics Bureau in Sweden[a] carried out a pilot study in 1998 with the purpose to commence a procedure for developing new methods of producing waste statistics applicable to industry. A new statistical method has been elaborated in which data based on waste statistics and economic data (e.g. number of employees and product quantity) were processed together and applied to four different industrial sectors. This initial study is based on too few units, therefore the results cannot yet be used for generally applicable waste factors.

Material flow method
Öko-Institut and Fraunhofer Institut für Systemtechnik und Innovationsforschung, in Germany[b] have gone a different way: based on the material flow and energy accounting, relevant industrial processes have been examined and waste factors calculated with the aim to link the factors with already existing data for air and water emissions of the described processes. Together, they form a part of the data pool 'Emission Source Structure', as it is used in the National Green Accounts in Germany.

Empirical method
To supplement the waste statistics, Ademe, France, has conducted a study[c] on non-hazardous industrial waste generated. Based on data and information of 5 500 enterprises, the results show the quantities of waste generated in relation to the number of employees in the examined enterprises.

In many cases the waste factor activities are an integrated part of the general development of environmental indicators or factors. For example U.S.EPA[d] developed twelve indicators to measure progress in the Resource Conversation and Recovery Act (RCRA) for three major components: waste minimisation, safe management and corrective action. Waste factors are used to report and compare quantities of waste generated in different industrial sectors, quantities of waste recycled, and trends in per capita waste generation (e.g. pounds of waste per person per day). The factors are compared with target values, which are set as nation-wide goals.

5.3. Waste factors at technology level

There is a great number of concrete models for the derivation and application of waste factors at technology level available, based on practical examples (with respect to the objective of this report only a limited number of reports has been chosen for reference [17 18 19 20 21 22 23]).

In many cases, models are based on the idea and principles of material flow analysis or Material Flow Accounting (MFA), and the Life Cycle Assessment methods (LCA)[24]. They often include economic analysis models as well. Those models provide a holistic and objective basis for both assessment and comparison, either waste generating processes or waste management alternatives.

In other cases simplified input-output models for functional units are being used, featuring the most relevant aspects of material flow and waste generation only.

Due to application of these models many economic operators have already made fruitful experiences. In most cases the knowledge gained has been used to detect

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[a] See Section II, Example 8
[b] See Section II, Example 3
[c] See Section II, Example 7
[d] See Section II, Example 11

the weak points and thus potentials for the minimisation of waste and subsequently to quantify the economic effects of appropriate counter measures (for examples covering different industrial sectors refer [25 26 27]). Therefore the described models offer tools which can be used for environmental management in companies, providing economic success as well.

Waste factors at technology level have also been proven as a valuable tool to create benchmarks for waste generation. They can be used to compare process efficiency and set waste reduction targets for industrial sectors or individual enterprises.

A few **examples** should be given in this context:

The complex task of developing waste factors at process level is presently already undertaken in projects with Europe-wide participation, e.g. EPIS[a]. EPIS focuses mainly on pressure indicators, but waste factors will be developed on material flow basis for defined production processes.

Also the activities of the European IPPC Bureau[b] on best available techniques in different production sectors should be considered. Based on Council Directive 96/61/EC, the IPPC Bureau elaborates documents which describe selected techniques and provide information on

- consumption and emission levels achievable by using each technique;
- the costs and cross media issues associated with each technique; and
- the extent to which each technique is applicable to the range of installations requiring IPPC permits.

The IPPC Bureau has already published first results in (draft) documents on best available techniques, giving detailed information about the material flow in installations in these industrial sectors[28].

Similar activities on both industrial sector level and technology level are carried out by U.S.EPA, office of Compliance Sector Notebook Project. The Office publishes notebooks on eighteen specific industrial sectors with the purpose of designing and implementing comprehensive, common sense environmental protection measures. The description and assessment of material flow and pollution output are two of the chosen key elements for this purpose[29].

Also several institutions which deal with waste minimisation on regional or national level in the EU Member States – such as ABAG[c] in Germany and ETSU[c] in the United Kingdom- and many individual enterprises[d] have already developed and applied waste factors for several industrial sectors. These factors are normally based on data and information on material flow ascertained in selected plants. They are widely acknowledged by practicians in industry and by industrial associations and used by enterprises as benchmarks and waste minimisation targets.

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[a] See section II, Example 2
[b] European Integrated Pollution, Prevention and Control (IPPC) Bureau, Seville
[c] see section II, Example 5
[d] see section II, Example 4

5.4. Warning signals

Waste factors do not state the causes or conditions of a certain waste situation. They are not supposed to be compared without in-depth analysis. This requires additional information and data about the source or activity: process technology, including process design, operational practices, maintenance; type and quality of material input; product characteristics; on-site treatment of effluents etc.

The following examples illustrate some of these aspects:

Example 1 – National level

Situation: At national level the waste generation per GDP (t/ECU) in two different countries may show a considerable difference.
Conclusion: This should not necessarily lead to the conclusion that waste management is practised in a different way and with different efficiency. The discrepancy could in fact be influenced by the different economic performance of the two countries.

Example 2 – Industrial sector level

Situation: The steel producing sector in nation A generates 150 kg of unprocessed slags per tonne of product. The same industrial sector in nation B produces only 15 kg/tonnes.
Conclusion: Since the reason for this difference cannot be the process technology, it appears that the EU regulation has been interpreted and implemented differently: in nation A the slags are declared as waste for disposal, whilst in nation B slags are declared as a co-product.

Example 3 – Enterprise level

Situation: A textile manufacturer A (finishing, dyeing) produces significantly more waste per EURO turnover, or per employee, or per square meter product than manufacturer B.
Conclusion: Assuming that the production processes in both enterprises are similar, this could mean that manufacturer A operates an on-site wastewater treatment plant in a highly efficient way, thus generating considerable quantities of waste sludge, whilst manufacturer B does not treat the wastewater at all.

Example 4 – Enterprise level

Situation: A manufacturer of a complex product (e.g. cars) states in his yearly environment report that he reduced significantly the specific waste quantity (kg waste per car) generated.
Conclusion: This could be based either on the implementation of cleaner production or simply on pure outsourcing of waste intensive production steps. This example demonstrates the necessity to clearly and explicitly define the system to be assessed.

Example 5 – Production process level

Situation: Manufacturers of fertilisers may generate different specific quantities of residues per tonne of product, even if in the examined plants the same technology is used.

Conclusion: The reason for the various waste factors could, for instance, be the different quality of raw material available, depending on geological situations.

Example 6 – Production process level

Situation: The waste factors (quantity of electroplating sludge per tonne of product or per square meter of product) of several examined electroplating manufacturers may differ significantly, despite the fact that all of them treat the effluents on-site according to best available technology.
Conclusion: The reason for the difference in waste factors could be caused by the shape of the product: e.g. galvanising screws will entail more sludge per tonne of product than galvanising big sheets of tin.

6. First assessment and conclusions

6.1. General considerations

A basic problem which concerns all studies is the question of **definition**. Normally the national waste nomenclature has been applied, and only a few studies refer to the European Waste Catalogue (EWC). This aggravates the direct comparison of waste types and waste data stated in the national reports. This can in fact lead to factors not transferable to other countries.

It has to be pointed out that none of the studies considered attempts to provide waste factors applicable on EU level. A basic condition for obtaining internationally applicable factors at the EU level will be the harmonisation of definitions.

Another problem lies within the general **terminology** used for the material input/output (e.g. raw material, waste, co-products), and the terminology used for specific waste types. It can be observed that different terms are used for either a waste or a raw material, or a term is used indiscriminately for two different waste or material types within the same language. For example, in the context of aluminium smelting the Spanish word 'escorias' is often used for salt slags as well as for skimmings. The problem multiplies when translating reports from one language into another.[a]

The development of waste factors requires clearly defined **system boundaries**. It is obvious that results will be different whether, for example, in the secondary aluminium smelting industry, the pre-treatment of raw materials is included or not. Another aspect related to system boundaries is the availability and inclusion of data on recycled material. It has to be clearly stated whether recycled wastes are recycled on-site or off-site.

All reports considered in this assessment provide waste factors that represent quotients of waste generated per **reference unit**. The reference units applied in most of the documents are either a unit of product (e.g. tonnes, number of pieces) or an economic unit (e.g. gross production in of a specific currency). Both

[a] Statistis bureaus, waste inspectorates, and public administration entrusted with waste related tasks are facing the problem of inadequate waste description and insufficient implementation of the EWC. This problem could be overcome by the elaboration of a EWC Manual, that describes in a brief but correct way the provenience of relevant waste types.

types of reference units have to be assessed thoroughly when applying the waste factors at different levels.

Factors with an economic reference unit bear the inconvenience that they depend on the actual market price of a product, which is subject to alterations. Therefore, the economic value does not always give a direct indication of production volume or quantity.

None of the examined studies refer to the life cycle of a **product** and the environmental impact caused by its use, recycling or disposal. But such aspects have to be taken into account at least at the macro-economic level. Political decision-makers have to consider the source-oriented waste factor as well as the environmental impact caused by a product.

All waste factors considered have in common that they do not take into account the **waste quality**. With respect to treatment and environmental impact, a small quantity of a highly toxic waste cannot be compared to a bigger quantity of a waste of minor hazard.

Based on the reports and literature available, a first assessment has been made regarding the key aspects:

- interested parties and corresponding levels of application (6.2.);
- availability and experiences (6.3.);
- methodology, framework and system boundary (6.4.);
- linkage to other environmental indicators (6.5.);
- quantitative and qualitative aspects (6.6.).

6.2. Interested parties and corresponding levels of application

The different levels at which waste factors serve as a tool can be distinguished as follows

- national and regional;
- industrial sectors;
- enterprises, production sites;
- technology: production process and sub-processes;
- consumer.

The respective interested parties and some example waste factors presented for each of these levels in the following table:

Table 3: Waste factors: levels, interested parties, and examples

Level	Interested party (customer)	Waste factor (example)
national and regional	political decision makers, statistic offices, economists, public administration	waste quantity per BIP, per inhabitant
industrial sectors	statistic offices, economists, industrial associations	waste quantity per product or financial turnover

enterprises, production sites	management, waste management authorities	waste quantity per product or financial turnover
technology: production process and sub-processes	management, engineer, waste management authorities	waste quantity per input of raw material or per product unit
consumer	private and industrial consumer, consumer associations	waste quantity per product bought

The results available from the different projects and studies in most cases are very complex and mainly of scientific interest. They have to be revised to make them applicable for political decision-makes, statistics offices or public administration, and to meet the criteria concerning interpretation and communication. Only a few studies deliver practical results which can be directly applied, especially for waste minimisation measures in enterprises.
At technology level there is a great number of non-co-ordinate activities, mostly at national and regional level. The results and information are in many cases of limited value, since goal, methodology and contents of the respective studies are not congruent and in most cases not transparent.

Most of the results offer waste factors for description and might be used as a reference, and under certain conditions for performance assessment as well as for projections. Still missing are, at technology level, factors which can be used as benchmarks, thus characterising the standard for clean technology.

6.3. Availability and practical experience

Despite the great number of activities and studies on waste factors, there is as yet no nationally and/or internationally accepted system or set of waste factors available for environmentally sustainable development.

The factors already developed at technology level as well as industrial sector level relate in most cases to industrial processes with great quantities of material flow, where the process itself is considered as a ‘black box’, and only a few input/output materials are involved. This might be suitable for sources like foundries, power plants etc., but certainly not for the description and assessment of complex multi-stage processes such as those found in the automotive, engineering and electrical industry.

Most of the information available is based on theoretical studies, thus comprising little information about the practical application of waste factors in waste management and the experience gained. In most cases waste factors have been used for the description of waste generation, either supplementing national/regional waste statistics or waste balances in companies. But there is little information about the use of waste factors as a tool to support minimisation activities, showing trends, assess performances or set benchmarks for industrial sectors or national level.

There is a lack of verified factors on the one hand and insufficient feedback about the practicability of waste factors on the other hand.

6.4. Methodology, framework and system boundary

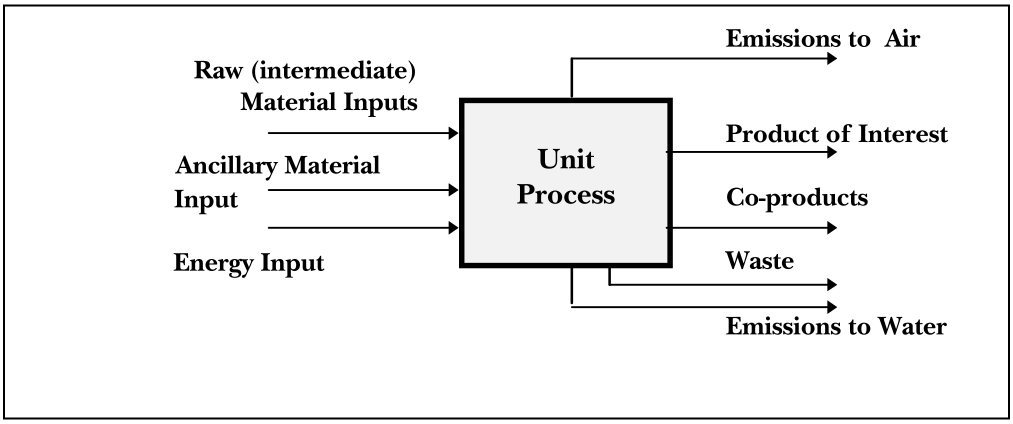
The results of the different studies and projects on waste factors are in most cases not directly compatible, since targets, methodologies, system boundaries, data sources etc. are different, and in many cases neither well-defined nor transparent.

Studies and projects on waste factors are based on different methodologies involving, either a bottom-up or top-down approach. This difference in the methodical approach might not affect the result – the waste factor itself – but hinders the direct comparison due to the difference in assumptions, data source, etc.

The studies and reports are also based on different conceptual frameworks, e.g. using the PSR-framework (pressure, state, response), DPSIR framework (driving force, pressure, state, impact, response; see Fig. 1). Most of the studies refer to indicators used for describing pressure and state, and therefore are not of direct use for the source oriented approach and the development of waste factors.

In many cases the principles of Material Flow Analysis (MFA) have been adopted, but not stringently: they differ to a great extent in the definition of goal and scope, system boundaries as well as functional/structural boundaries, definition of systems (industrial sector, enterprise, production process), consistency and comparability of data, aggregation etc. The family of standards on life cycle assessment (LCA) are suitable to define system (waste source), system boundaries, data collection and data quality concerning material flow and inventory.

Fig. 4: Conceptual example of unit process description



Due to the fact that methodical approach, framework and system boundary for the derivation of waste factors are not standardised, the waste factors available are not compatible, and their comparability is limited. To facilitate a harmonised approach work on waste factors should be based on common and standards and definitions.

6.5. Linkage to other indicators

Waste factors are not a 'stand-alone solution'. According to their purpose they should be linked to other environmental factors and indicators or to economic data. Especially for political decisions it is vital to fully describe and assess the environmental impact of the source of emission, e.g. a technical process.

At national level this has been recognised, and for the indicator discussion at international and national level (e.g. EU[a] , UNCSD[b] , OECD[c] , the Netherlands[d], Germany[e], U.S.EPA[e]) a number of highly aggregated key indicators have already been specified.
It also has to be considered that waste factors as well as other environmental indicators should be in tune with each other;

- if they are used for the same purpose; e.g. the Environmental Programme of the Netherlands, which comprises indicators for the themes climate change, acidification, eutrophication, toxic substances, waste disposal and groundwater depletion to give a clear and succinct picture of environmental progress, and which has been developed to support political decision-makers at national level, or
- if they are used to describe the environmental condition or performance of the same object, e.g. the work on BAT as done by the IPPC Bureau, where all types of emissions of a technique are considered.

Waste factors and air emission factors – an exemplary comparison

Compared to other environmental factors the work on air emission factors is quite advanced. Therefore it might be helpful to use the results and experiences gained in this field for a comparison with the work on waste factors:

In analogy to the CORINAIR inventory, waste factors should allow for the evaluation of waste quantities generated as a function of some variable or significant data of the activity in question.

Nevertheless, there are some fundamental differences between wastes and air emissions with respect to their environmental impact, which result in differences in the required analyses. Due to this, the CORINAIR methodology is not applicable directly for the establishment of waste factors:

Despite the fact that air issues and also CORINAIR have a longer tradition than waste issues, in the case of air emissions, the contaminants are quite specific[a] and their generation depends to a great extent on the technology applied. Therefore, the theoretical generation of a contaminant can be determined by means of a

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[a] European Community Programme of policy and action in relation to the environment and sustainable development (5th EC Env. Action Programme), as well as activities, studies and reports based on this programme (e.g. Environmental Pressures Indices Project); European Commission, Brussels/Belgium

[b] UNCSD developed a set of environmental indicators to provide solid basis for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment systems (see also Agenda 21).

[c] OECD has specified a set of core indicators for environmental performance reviews. The indicators correspond to the PSR framework; OECD Core Set of Indicators for Environmental Performance Review; OECD, Paris; 1993

[d] The Environmental Programme 1997 - 2000 of the Netherlands describes the environmental policy and the use of indicators for target groups (e.g. agriculture, industry, energy...) and for themes (e.g. climate change, hazardous substances, ...);RIVM, The Hague/the Netherlands 1997

[e] The „Programme of Key Environment Measures" (Draft) of the Fed. Ministry for the Environment, Nature, Conservation and Nuclear Safety in Germany aims to develop a „Environmental Barometer", which will comprise indicators for the environmental policy areas climate, air, soil, nature, water, resources (incl. waste); Source: Nachhaltige Entwicklung in Deutschland; BMU, Bonn/Germany; 1998

[e] Resource Conservation and Recovery Act (RCRA); RCRA Environmental Indicators - Progress Report; EPA/USA; 1992 ff

[a] Normally described in terms of CAS (Chemical Abstract Services) Registration Number

relatively simple equation (example: combustion of fuel leads to an amount of SO_2 generated depending basically on the characteristics of the fuel).

In the case of waste, this simple calculation cannot be applied. In most cases, wastes have different qualitative and quantitative characteristics, depending on the technology, the process operation and the actions of the personnel involved, in spite of pertaining to a particular waste group, with a specific waste code to characterise them. The quantity of a waste generated in an industrial activity indicates the degree of inefficiency/efficiency of a process, as well as of the operational practice.

In the case of air emissions, the environmental impact is often immediate. Thus, a contaminant emitted and its effect on persons and the environment can be evaluated by means of functions, which relate the probability of a negative effect to the level of exposure (Concentration and time of exposure).

On the other hand, the environmental impact of wastes depends, apart from their intrinsic characteristics, on the type of treatment they undergo. For example: the impact of untreated fly ashes is quite different from the impact caused by fly ashes treated and disposed of according to the state of the art. In the latter case, the environmental impact is related to the treatment applied and to the transport of the waste to the treatment facility.

The conceptual difference between waste and sub-product is not considered in the case of air emissions. However, for wastes this difference is important, as the total quantity of wastes managed depends on the quantities totally or partially recovered as sub-products.

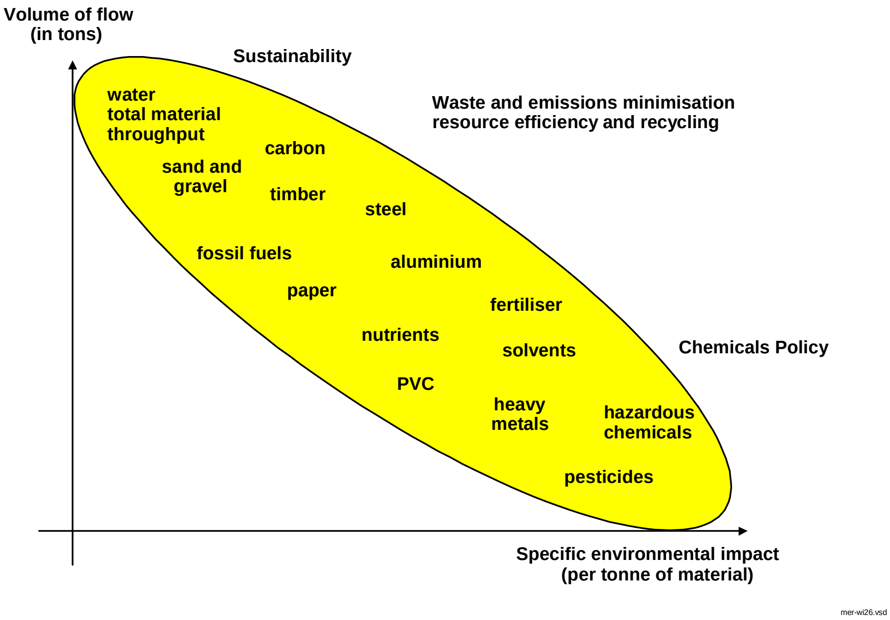
Air emissions are described using the name of the chemical substance. They are named and classified world-wide by CAS. This advantage does not exist in the waste business.

Due to the advanced level within other areas than waste, further development of waste factors could therefore consider the data and information already gathered for the derivation of other environmental factors and indicators.

6.6. Waste factors – quantitative and qualitative aspect

All waste factors have in common that they only take into account the quantity of waste (mass or volume) and do not consider the quality of waste (e.g. toxicity). To assess entirely the environmental impact related to waste generation, flow, and treatment the overall view comprising quantity and quality is needed (see fig. 5). For this purpose additional data and information, are required.

Fig. 5: **Material flow and specific environmental impact – qualitative and quantitative aspects (example[30])**



7. Conclusions and recommendations for further work

Based on this overview the following conclusions can be drawn:

- Waste factors are a useful tool in waste management:
  - to measure waste minimisation efforts;
  - to illustrate and control both waste generation and flow;
  - to detect inconformities in implementation of EU regulations at national level and to guide corrective action, and
  - to make projections and scenarios on future waste arising.
- Comprehensive and reliable databases and information, as needed for the derivation of waste factors, are not available or at least hard to obtain.
- A common model for the derivation and application of waste factors, as well as for the development of projections at European level, does not exist yet.
- There is a lack of verified factors on the one hand and insufficient feedback about the practicability of waste factors on the other hand.
- There is a common understanding that waste generation is linked to economic activity, but that the detailed aspects are not yet fully understood.
- The derivation of waste factors and its application at different levels is a very complex and extensive undertaking.
- Waste factors are not a 'stand-alone solution'; according to their purpose they should be linked to other environmental factors or indicators and to economic data.
- Waste factors do not state or even explain the causes or conditions of any waste situation; therefore the practical application of waste factors requires additional information to be available.

- A number of parallel projects are carried out by various institutions at EU and national level, aiming at the identification and derivation of waste factors.

Based on these findings, further work on waste factors might consider:
1. the nomenclature of the EWC, regardless amendments will be made in the near future[a];
2. the DPSIR framework, waste source being an element of the driving force;
3. the definitions and terminology given by internationally standardised methods of Life Cycle Assessment (ISO 14040 ff);
4. the overall view comprising quantity and quality of waste;
5. the data and information already gathered for the derivation of waste factors as well as other environmental factors and indicators, e.g. EPIS, IPPC Bureau, ETC/Air Emissions.

[a] Statistics bureaus, waste inspectorates, and public administration entrusted with waste related tasks are facing the problem of inadequate waste description and insufficient implementation of the EWC. This problem could be overcome by the elaboration of a EWC Manual, that describes in a brief but correct way the provenience of relevant waste types.

SECTION II

Examples
The following examples supplement the explanations given in Section I of this Technical Report.

In almost every EU Member State as well as on EU level, activities are undertaken to develop waste factors. The examples are not restricted to waste factors only, but also demonstrate interesting results on the development of waste indicators. The examples offer only a small excerpt of the great variety of studies and reports about waste factors. They may illustrate the different approaches, the different methodologies used, and the difference in goals and findings.

In most cases the activities are focused on the development of waste indicators or environmental indicators in general, rather than on the development of source orientated waste factors itself: e.g. the UNCSD develops a set of environmental indicators, and in Germany seven key objectives en route to sustainable development are summarised in an 'Environmental Barometer for Germany'. In both cases the generation of waste plays only a minor part of the project.

The eleven examples are chosen to illustrate the wide range and variety of activities. It should be pointed out that they do not give a complete and exhaustive overview on all activities in the EU Member States.

NRCs are invited to contribute data and/or further examples in order to complete the picture of the issue.

Example No.	Institution
1	ETC/W
2	Eurostat, Brussels, Belgium
3	Öko-Institut, Germany; Statistisches Bundesamt, Germany
4	Badische Stahlwerke, Kehl, Germany
5	ETSU, United Kingdom; ABAG, Germany
6	Ministerium für Umwelt und Verkeh, Baden-Württemberg, Germany
7	ADEME, France
8	Statistics Sweden, Sweden
9	Statistics Norway, Norway
10	Ministry of Housing, Spatial Planning and the Environment, the Netherlands
11	U.S.EPA, USA

Example 1 Total waste generation versus economic productivity

Institution: European Topic Centre on Waste

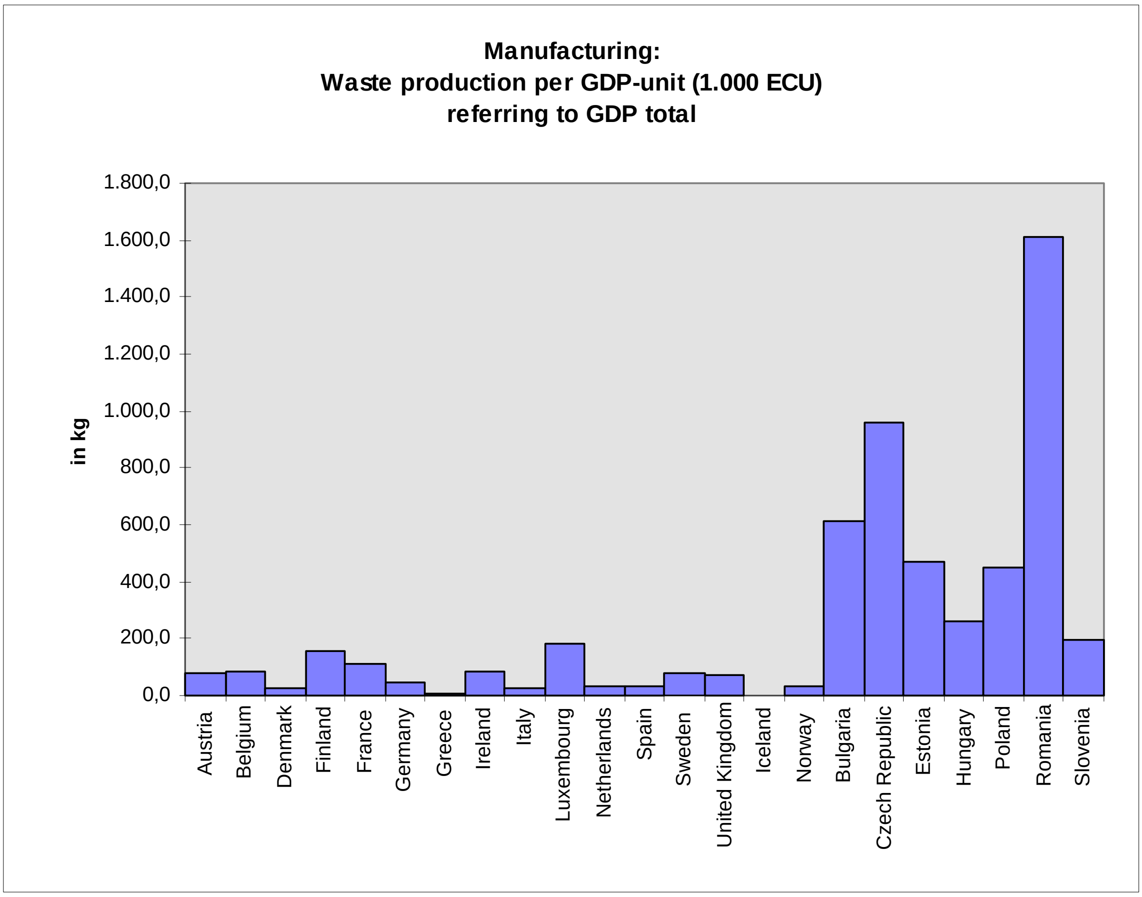
Level: National

Industrial sector: All types of industrial sectors

Waste type: All types of waste

Outcome: Ailing economies seem to entail insufficient waste management with regard to waste minimisation. But very low GDP pretend more inefficient technologies than in reality exist. The example clearly shows that further information and data are necessary to assess the waste situation and its impact onto the environment and to plan activities to improve both the treatment and the minimisation efforts.

Fig. II.1: Waste factor on macro-economic level



Example 2 Establishment of the Environmental Pressure Information System (EPIS)

Institution: Statistical Office of the European Communities – Eurostat, Brussels, Belgium

Level: Derivation: technology level
Application: technology level, production sector level, national level

Industrial sector: All sectors (priority list)

Waste type: All types of waste

Outcome: EPIS[31] is based on the methodology of conventional material flow balances: the input of material and energy into a system or process are considered equivalent to the accumulation and the output of products and other emissions (waste, waste water, air emissions , etc.) as result of the process within a defined period. With this conceptual framework EPIS fits easily into both the present used system of sectional economical statistics and the national account.

The model links between environmental data and economic statistics, to consumption and environmental impacts, and to pressures coming from it. EPIS will contribute to the development of pressure indicators by providing data on material flow and emissions of selected harmful substances into air and water. This opens the perspective to calculate the accumulative environmental pressure of different final products, results which are important for the consumption sector and the development of environmentally friendly products.

For waste generated in a production process both the technology and the material input are considered. The secondary wastes from on-site waste water or exhaust gas cleaning are considered separately. Thus leading to the equation:

$$W\gamma\varphi w = k4\gamma w * S\gamma t + k5\varphi w * R\gamma s$$

with $W\gamma\varphi w$ = waste generated in the process γ and in the additional environmental process φ
$k4\gamma w$ = coefficient for the quantity of waste w of the process γ
$S\gamma t$ = product t of the process γ
$k5\varphi w$ = coefficient for quantity of waste w of the environmental process φ
$R\gamma s$ = waste for recovery of the process γ

EPIS started in 1994 with a pilot phase involving France, Germany, Italy and the Netherlands. The present phase includes pilot projects in Austria, Finland, Norway, Spain and Sweden in which consistent data structures will be developed, linking economic statistics and process specific data. In addition, input-output data for specific processes will be developed. EPIS is part of Eurostat's project on Environmental Indicators and Green Accounting. Future work will involve the expansion of EPIS to other Member States, production of an EPIS manual, and the integration into the ENVSTAT database.

Example 3 Material and energy accounting and calculation of minimisation costs in the National Green Account[32]

Institution: Öko-Institut e. V., Darmstadt, Germany, for the Statistisches Bundesamt, Wiesbaden, Germany

Level: Derivation: technology level (industrial processes)
Application: all levels

Industrial sector: All sectors

Waste type: All types of waste

Outcome: In a first step 48 relevant industrial processes were selected. For these processes material flow balances have been established. In a following step the data have been aggregated, thus forming a core set of 20 material factors and waste factors. These sets of factors can be linked to already existing factors for air and water emission of the described processes. All factors together form a part of the data pool 'Emission Source Structure', as it is used in the National Green Account[a] of the Statistics Office in Germany. The factor sets can be multiplied with product relevant data, thus forming absolute numbers.

In a second part of the study the authors derived a methodology for the selection of cost effective processes for the minimisation of waste. The methodology has been tested on an exemplary basis for three different industrial processes: production of cement, paper and steel.

For each of the selected processes the system boundaries were defined. It normally includes the production process itself as well as additional environmental measures, e.g. waste water treatment or exhaust gas cleaning on site. In a second step the material input (raw materials, auxiliary materials, energy, water etc.) as well as the material output (product, waste, water etc.) were defined and described both by quality and quantity. The respective data and information for the material balances and for the energy balances were compiled by using data and information about the process design and from the waste statistics, production statistics, scientific reports etc.

The results for each of the selected processes are summarised in tables, naming both the input and output material as well as their respective quantity in t or kg. For the different waste types factors have been derived by relating the quantity of waste to the quantity of product, e.g. 15 kg slags per metric tonne steel produced in an electro steel plant.

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[a] In the German version of the report the term *Umweltökonomische Gesamtrechnung* has been used.

A similar study has been done by Fraunhofer-Institut für Systemtechnik und Innovationsforschung, Karlsruhe´, Germany, for the most relevant industrial processes and hazardous waste types[33].

The main objective of this project was the development of a procedure for the identification and selection of relevant waste generating processes as well as the development of waste factors[a] for specific industrial processes. These factors should be integrated into MEFIS[b] , which is used for the national 'Green Account'.

The results are given in quantity of waste related to quantity of product:
Waste Factor WF = waste in t/product in t.

Example for the sector foundry industry in Germany in 1993:

WF = disposed used foundry sands in t / cast metal product in t
WF = 859.847 t / 2,939,000 t = 0.29

Example 4 Steel industry, secondary smelting and hot rolling

Institution: Badische Stahlwerke, D-77694 Kehl, Germany

Level: Enterprise

Industrial sector: Steel industry, secondary smelting and hot rolling

Waste type(s):
10 02 02 unprocessed slag
10 02 03 solid wastes from gas treatment
10 02 05 other sludges (in this case: milling scale)
10 02 06 spent linings and refractories

Outcome:
Waste factors (kg per tonne steel produced):
10 02 02: 148
10 02 03: 8

10 02 05: 10
10 0206: 6

These figures can be analysed and compared to experiences of other Steelworks or to literature results. Basis for benchmarking. Dismantling discrepancies in the understanding (see figures in example 3).

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[a] In the German version of the report the term *Abfallkenziffern (waste reference number)* has been used.
[b] MEFIS - Material and Energy Flow Information System.

Example 5 Minimising used sand in foundry industry

Institution: 1. ETSU, Harwell, Oxfordshire, United Kingdom[34]
2. ABAG Abfallberatungsagentur, Fellbach/Germany[35]

Level: technology level (production process), industrial sector level

Industrial sector: foundry industry

Waste type(s): foundry sand, EWC 10 09 02

Outcome: The above named institutions have independently carried out surveys on foundries in United Kingdom (58 enterprises) and Baden-Württemberg, Germany (35 Fe-foundries; 60 non-Fe-foundries) respectively.

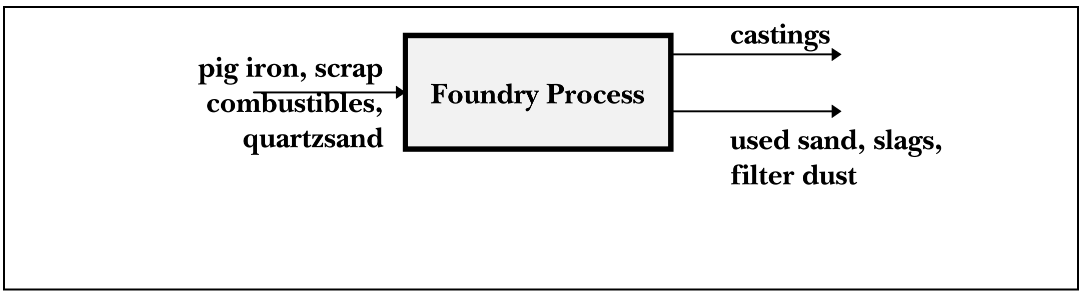
In both cases the results were given in quantity of used sand to quantity of net production of castings: Waste factor = used sand in t / net production in t.

The waste factors of the examined enterprises showed a wide range, e.g. for Fe-foundries between 0.2 and 2.4, with a mean value of about 0.5 in both surveys. In both cases the results of the surveys were used for an action plan with the aim, to

- use the highest amount of reclaimed sand possible in sand mix;
- reduce new sand additions to less than 2% if possible;
- evaluate techniques for reclaiming greensand to new sand quality (where large volumes of spent sand are disposed of);
- minimise sand-to-liquid metal ratios;
- review purchasing contracts for sand and other greensand components, and
- increase metal yield.

In Baden-Württemberg the action plan led to an improvement in almost all foundries, thus reducing the total quantity of used sand generated in Fe-foundries by 70 % and in non-Fe-foundries by 79 % within a period of 5 years (1992 to 1997). This led to the additional result that waste factors for BATNEEC could be developed and used as benchmarks by other enterprises in the foundry sector.

Fig. II. 2: Fe-foundry – simplified scheme



Example 6 Municipal waste in a 10 million inhabitant EU-Region, industrialised to a high extend

Institution: Ministry for the Environment and Transport, Stuttgart, Germany

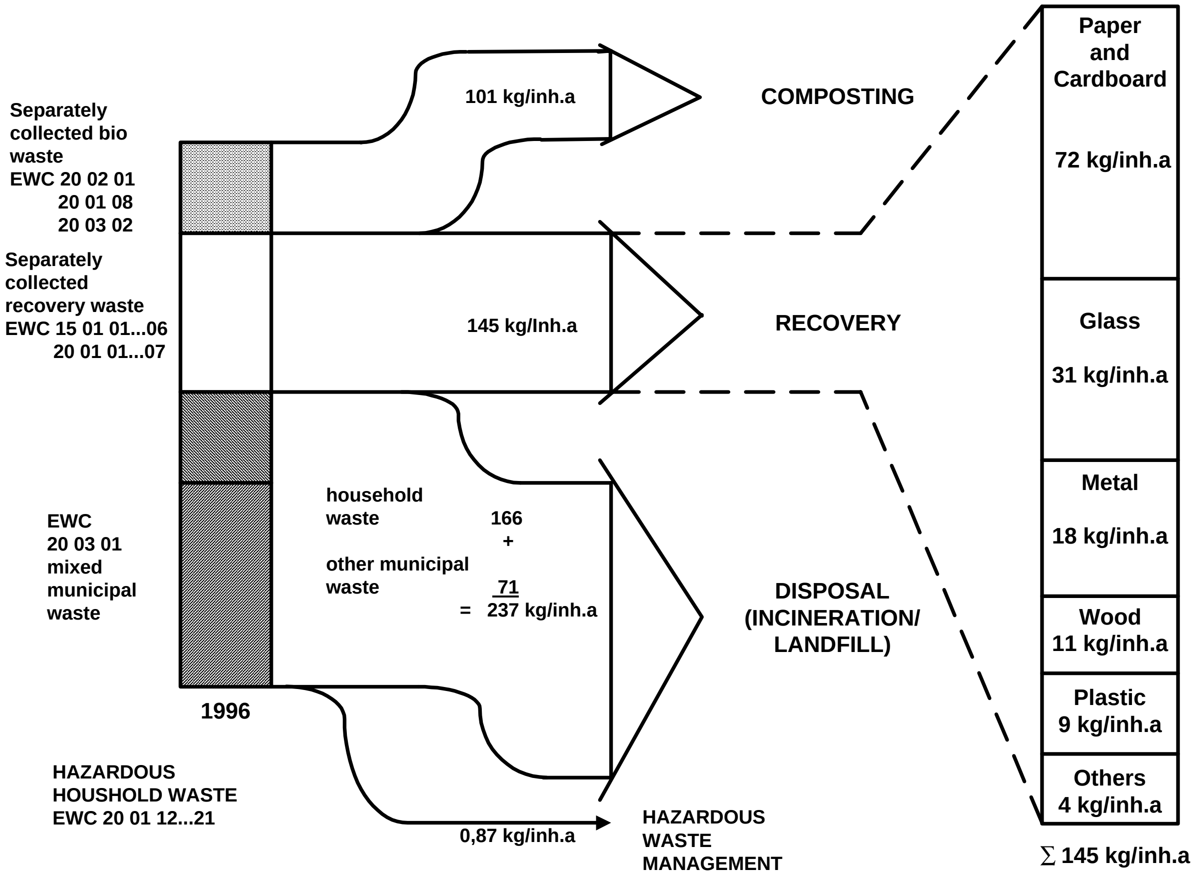
Level: Regional (10 million inhabitants)

Industrial sector: Private households and small craftshops, small enterprises

Waste type(s):
15 01 01 ... 06
20 01 01 07
20 01 12 ... 21
20 03 01

Outcome: Referring to figure II.3, benchmarks for an industrialised EU region are obtained. Measures to recover waste have been established and intensified. A comparison to other EU Regions might give hints for further efforts or not. The waste factors on biological waste can give some signals to proceed further on with some caution since the compost market tends to be saturated if certain benchmarks are overpassed. The waste factors obtained can be of use for the proposed draft of the EU Directive on Landfills which requires a reduction of organic load being landfilled.

Figure II.3: Municipal Waste Flow in 1996 per inhabitant distinguished by different fractions and treatment options



Example 7 Industrial waste generation related to size of enterprises[36]

Institution: Ademe Agence de l'Environnement et de la Maîtrise de l'Energie, Paris

Level: National
Industrial sector

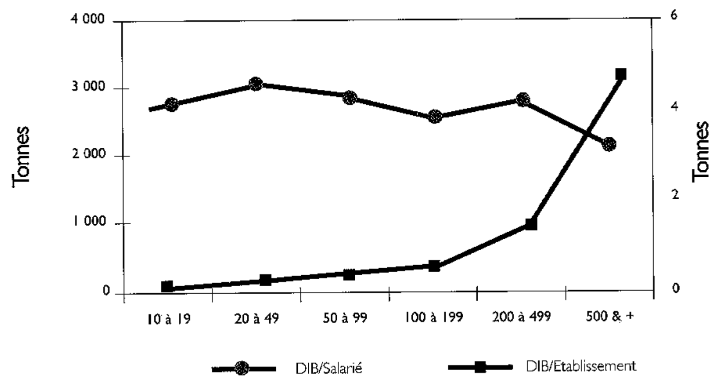
Industrial sector: 17 main industrial sectors, defined by NACE

Waste types: Non-hazardous industrial waste materials: glass, metal, plastics, rubber, textiles, paper and card board, wood, leather, others

Outcome: Ademe carried out studies on non-hazardous waste generation in 1996. The data and information are based on a survey of 5.500 enterprises, which responded to a comprehensive questionnaire send out by Ademe.

Beside the total amount of waste generated in both the surveyed industrial sectors and regions the results show the quantities of waste generated in relation to the number of employees in the examined enterprises.

Fig. II. 4: Annual production of industrial waste in relation to number of employees per production site



Note: DIB/Etablissement = non hazardous industrial waste per enterprise
DIB/Salarié = non hazardous waste per employee

Example 8 Waste factors – an initial study[37]

Institution:	Statistics Sweden
Level:	National Industrial sector
Industrial sector:	Selected sectors: paper/pulp, printing, motors and furniture industry
Waste type(s):	Non-hazardous waste, not specified
Outcome:	The purpose of the initial study is to commence a procedure for developing new methods of producing waste statistics applicable to industry. By processing basic data from the industrial waste survey 1993, together with other data (number of employees, quantity for sale, quantity manufactured annually, sales value), the study aims at finding 'auxiliary variables'.

The results of the study indicate that the data material which in the first place may be relevant for simplified studies has been examined and is evidently suitable for combining to a common material, a statistical method that calculates the relation between waste quantities and various auxiliary variables from other statistics can be used in simplified studies to estimate waste quantities on the basis of information concerning e.g. handling of raw products, power consumption and/or products manufactured.

The method has been applied to four different examples, demonstrating the relation between quantity of waste generated by a specified industrial sector and available industrial and product variables. For the printing industry, for example, (NACE 222; based on 7 observations) the following formula has been derived:

$$GEN = 25.85\ EMP + 0.123\ VALUE + 0.123\ QUANT\ 1 + 0.889\ QUANT\ 2 - 4601.7$$

with:

EMP	number of employees
QUANT 1	quantity for sale
QUANT 2	quantity manufactured annually
GEN	total quantity of non-hazardous waste
VALUE	sales value in thousand SEK for products manufactured

The authors point out that a vast number of variables exist, especially in industrial statistics, and that it is difficult to choose significant variables; the industrial sectors must be 'homogenous' concerning production, products and types of waste; the initial study is based on too few units, therefore the results can not be used for generally applicable waste factors yet.

Example 9 Future waste generation – forecasts on the basis of a macroeconomic model[38]

Institution:	Statistics Norway, Oslo
Level:	National
Industrial sectors:	Manufacturing industry
Waste type(s):	Hazardous waste
Outcome:	In the report the outcome is summarised as follows: 'The analysis shows that macro-economic models can be used to estimate changes in key economic variables which explain waste quantities. The key variables and assumptions of the general equilibrium model MSG-EE (Multi-Sectoral Growth – Energy and Environment) are used to describe the trends in various types of waste in the simulation period, up to the year 2010. Generated quantities of waste are found to rise over the simulation period both in terms of per unit produced and per capita. This occurs in spite of technological changes embodied in the MSG-EE, which in itself results in reduced quantities of waste per unit produced. Wastes in the production sectors are generally linked to the use of tangible factor inputs, i.e. materials used in production (material inputs). During the projection period, material input is expected to become relatively cheaper than other factor inputs, thus making it profitable to substitute materials for other factor inputs. This substitution effect in most production sectors dominates over increased efficiency due to technological progress. Therefore waste quantities rise faster than does output. The increase in quantities of waste in the period to 2010 is generally about 35% to 60%, depending on the type of waste. The projections reflect future development, given that no waste reducing actions are taken.'

The following formula has been developed:
$Aij(t) = Uij(t) * Aij(to) * dij(t)$

with: $Aij(t)$ quantity of waste type j in sector i in year t

$Uij(t)$ index for the growth in the respective explanatory variable (value of production, value of material input, value of consumption, measured at constant prices),
(for the base year to: Uij(to) = 1)
$dij(t)$ parameter, which allows for an exogenous shift in the waste quantity (effects influence the generation of waste, e.g. political measures)

Aij(to) is obtained from the statistics, with *to* equal to 1994 for waste generation in manufacturing industry.

Example 10 The Netherlands environmental programme 1997 – 2000[39]

Institution: Ministry of Housing, Spatial Planning and the Environment, The Hague, the Netherlands 1997

Level: National

Industrial sectors: All

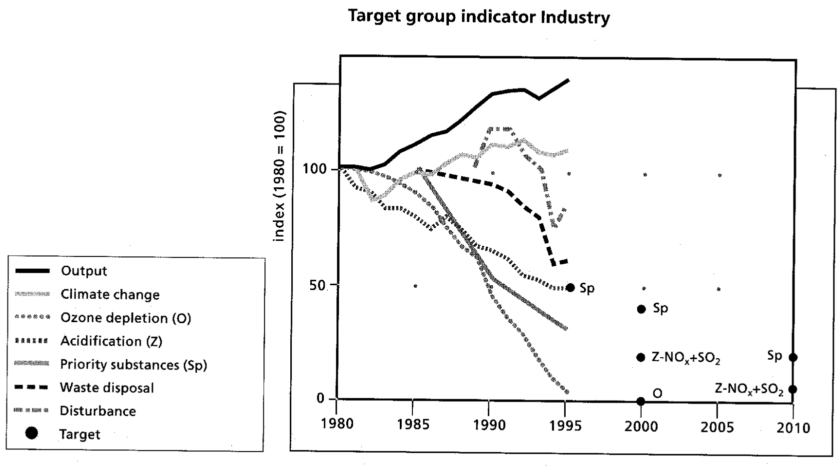
Waste type(s): Total amount (summarised)

Outcome: Indicators are considered as main elements to give a succinct and clear picture of progress in implementing environmental policy and the effects thus achieved for the environment. These indicators contain compressed data and are calculated each year by the National Institute of Public Health and Environment.

Target group indicators and theme indicators are used. A target group indicator shows the trend in the contribution made by the target group (agriculture, industry etc.) concerned to relevant themes (climate change, toxic and hazardous substances, waste disposal). A relevant theme is one where the target group accounts for at least 10 % of the total environment load.

The graph shows an example of the target group indicator industry: during the period 1980 to 1995 the volume of waste landfilled, discharged and incinerated fell by 39%, despite the increase in production output.

Fig. II.5: Target group indicator 'industry'



Example 11 RCRA environmental indicators[40]

Institution: EPA Environmental Protection Agency, Office of Solid Waste, USA

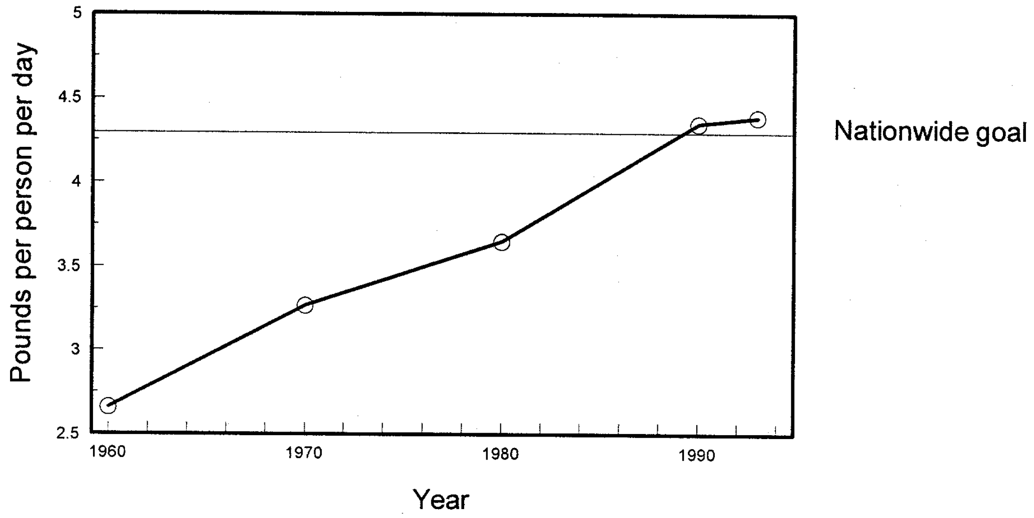
Level of application: National
Industrial sector

Industrial sector: Not specified

Waste type(s): Hazardous and non hazardous waste

Outcome: The OSW began reporting the 12 indicators in 1993; updates are made on a regular basis. The example in (fig. II.7) shows the trends in per capita municipal solid waste generation for the period 1960 – 1993:

Fig. II.6: Trends in per capita municipal solid waste generation, 1960 – 1993 (indicator no. 2)



The OSW claims that to remove the population growth effect on MSW generation, it is useful to evaluate per capita generation. The example shows that past trends toward higher total MSW generation rates are attributable to population growth as well as increases in per capita waste generation. From 1990 to 1993, per capita waste generation increased only very slightly – from 4.35 to 4.39 pounds per person and day. This may be due, at least in part, to source reduction measures. The reported indicator for the year 1993 is still above EPA's current goal for per capita waste generation of 4.3 pounds per day.

SECTION III

Comparison of waste factors and their applicability in the foundry industry and secondary aluminium smelting industry

1. Introduction

Based on data and information given by a few reports selected as examples, the differences between waste factors, and their development and application can be demonstrated. For this comparison two industrial sectors have been chosen: the foundry industry and the secondary Al-smelting industry. Both sectors are well known in all EU Member States and have been examined in several studies on waste factors and environmental indicators.

2. Comparison

2.1. Foundry Industry

2.1.1. Reference UBA/D[41]

The study considers the waste generation in seventeen major industrial sectors in Germany. The report mentions that WF in kg waste per tonne product are generally applicable at company level, sector level, and macro-economic level. At company level, it can be used for benchmarking as well as for target setting and control of waste prevention and minimisation measures in general.

The information on the methodology used in the study is scarce, especially with respect to the data assessment. The raw data utilised are taken from official statistics on production of the industrial sectors (aggregated company data for all parts of Germany).

There are indications of data gaps, but no explanation about any reason, nor what was the basis for the estimations made to fill these gaps. Information on these aspects would be essential in order to evaluate the validity and transferability of the factors to countries others than Germany, or to compare them with factors determined in other studies.

For some of the industrial sectors the author of the study considers it more adequate to focus on a segment typical or representative for the entire sector, thus limiting a characteristic quantity. This is not explained further or demonstrated by an example.

Factors have been derived for the years 1990 and 1993. The author indicates the problems related to the availability of data for 1990, due to the effect of the German reunification and the dramatic change of economic conditions. Thus the time series of data and derived factors comprises only two years, and is not representative for all parts of the Federal Republic of Germany. Therefore, an application of the factors for comparison with other countries, or even their transferability to other countries seems questionable.

Taking into account the indicated difficulties, the author considers the factors generally applicable for:

- Target setting and control of waste and 'special waste' prevention and minimisation measures on the sector and even macro-economic level, without further specification. This can be agreed upon, providing a follow-up of the study, in order to have longer time series available.

- Comparison of the evolution of the factors over time. In this case the factors can give indications where further analysis is needed, in order to find the reasons for the changes. This application requires longer time series as well.

- Determination of state-of-the-art technologies. This may be feasible considering the mere factor unit kg of waste or special waste per tonne of product on the technology/process level. On the aggregated level as given in the study, it is not possible, as neither the waste types nor the waste generating processes are considered.

- Benchmarking within an industrial sector. This is doubtful at least for sectors with a broad production spectrum. For homogeneous sectors, it can be subscribed with some restrictions. For example, the foundry sector is quite unique regarding casting and mould production processes, but the waste generated (in this case above all the sand) depends a lot on the specific product and on the magnitude of production.

- Comparison of different industrial sectors. This is applicable, when only the production process is regarded. The author gives as an example the comparison of the production of leather goods and the production of mineral oil refining. He states that the first generates considerably more hazardous wastes than the latter per tonne of product, indicating though, that in the case of mineral oil refinery the contaminants remain in the product. This statement may question the utility of such a comparison as discussed in section 1, part 7 'General Considerations'.

2.1.2. Reference ABAG[42]

The factors provided in this study have been elaborated for minimisation and cost reduction purposes, as indicated in the objectives of the study. Therefore, they are directly applicable only for comparison of companies with similar characteristics.

A further application on the sector level requires information on the sector within a geographical area. The information needed would include distribution of the companies by product type, company size, production volume etc. This is because the generation of used foundry sands depends to a great extent on shape and size of the cast pieces, as well as on the metal.

Assuming a more or less uniform distribution of companies with respect to the above mentioned aspects, the factors can be used on the political level for target setting in global minimisation. The factors have successfully been used as targets in the voluntary agreement between the State of Baden-Württemberg and the Foundry Industry Association with the goal to reduce the disposal of used sand by approx. 50%.

The ratio sand/good product is used in Germany, but not in other countries. Therefore, it does not serve for comparison between countries of the EU. Nevertheless, this ratio allows for relating the amount of this specific waste to production numbers. This facilitates a future application at the macro-economic level.

The restriction to the specific waste type ‘foundry sands’ bears the advantage of comparability between countries. This way the difference in classification (special waste in Germany, not hazardous waste in the EWC) does not influence the comparison.

2.1.3. Reference FhG-ISI[43]

The study provides two types of waste factors: tonnes of waste *generated* per tonne of product or per economic reference unit, and tonnes of waste *disposed of* per tonne of product or per economic reference unit. The differences in the raw data and in the factors are considerable. The term ‘wastes disposed of’ includes waste for final disposal as well as wastes for recycling. It is not clearly stated whether recycling in this case means off-site recycling only. The big numeric differences between wastes generated and wastes disposed of leads to the assumption that the greater part of the wastes generated are recycled on-site, though no explicit indication is made on that.

The applicability of the factors can be assessed as follows:

Comparison of development over time and projections: the time series – comprising data for two years only – are not sufficient yet. Changes in the factors over time only indicate the need for detailed analysis of the reasons, in order to avoid misinterpretation.

The use for comparison between countries will be limited, due to the specific German reunification effect and the drastic economical and political changes.

Comparison at company level for benchmarking: the use of the factors for benchmarking purposes seems problematic, as the system boundaries are not clearly defined. In the case of foundry sands, the internal differences of the foundry sector are not taken into account.

Comparison between sectors: the study provides some factors related to a production unit, and some factors related to economic reference units. It seems questionable, whether these two units are comparable, as prices may alter and do not always reflect the production volume.

Application at the macro-economic level: the factors can be used at the macro-economic level, but with some limitations with respect to the comparability of reference units. Application for waste management planning, as well as for target setting and control of prevention measures seems feasible. Nevertheless, it always has to be taken into account that the factors are not self-explanatory, and that the reasons for a change may be manifold.

The report states that among the companies there is a tendency to reclassify hazardous wastes in order to save high disposal costs. Another practice to save disposal costs and to avoid environmental taxes is to declare wastes (re-usable, recyclable) by-products. These wastes might end up in recycling or recovery processes environmentally not sustainable.

2.1.4. Reference ETSU[44]

The ratios given in the report are not meant as factors applicable on any other than company level. Their purpose is benchmarking within the foundry sector, with a special view to cost reduction.

Nevertheless, in combination with detailed production statistics, they may be used for projections on future waste arising, as they split the foundry sector into different sub-sectors and take into account the variations in production and raw materials used.

It has to be stated, though, that the ratio of new sand purchased per tonne of product does not take into account the additives used in mould and core making. The amount of sand to be disposed of is somewhat higher than the amounts of new sand purchased, due to these additives.

The changes in the ratios can indicate a technological improvement, but still require in-depth analysis, because the amounts of sand recycled and disposed of depend on many factors inherent to the particular foundry plant, as discussed before.

Table III.1: Development of waste factors for the foundry industry – selected examples

	UBA/D[a]	ABAG[b]	FhG-ISI[c]	ETSU[d]
Objective	Create environmental factors/indicators • benchmarks and state of the art for industrial sectors • differences between sectors • changes over time (implementation of new technologies etc.)	Minimisation and prevention of used foundry sands Calculation of minimisation and disposal costs	Elaboration of waste factors for specified industrial sectors Determination of waste streams Linkage with economic statistics	Minimisation of used foundry sands Calculation of minimisation and disposal costs
Approach	Bottom-up	Bottom-up	Bottom-up and top-down	Bottom-up
Industrial Sector	17 industrial sectors; one example: foundry industry	Foundry industry only	24 specified industrial sectors; one example: foundry industry	Foundry industry only
System Boundary	Industrial sector not clearly specified (e.g. relation to production process)	Defined production process: metal smelting, production of moulds and cores, casting, shaping of cast pieces, sand recycling on site, finishing of cast pieces	Industrial sector as specified by SYUM: no relation to production process	Casting process; not specified in detail
Level	Industrial sector;	Technology	Industrial sector;	Technology

[a] See Lit. 42
[b] See Lit. 43
[c] See Lit. 44
[d] See Lit. 45

	company level	(process; company)	technology level	(process; company)
Data Base	National statistics (waste, economy); 1990, 1993	On-site measurement in eight foundry plants; statistics (national; industrial association) 1991 – 1996 (all years)	Statistics (waste/economy) and literature; 1984, 1987, 1990, 1993	Empirical data from 105 foundry plants
Waste Types	Waste and hazardous waste (not specified)	EWC	EWC	foundry sands
Waste Factor	Total waste amount: 585 – 603 *kg* of waste per *t* of product; hazardous waste: 50 – 82 *kg/t*	Used foundry sand: 280 – 510 *kg* per *t* product	Foundry sand: 340 – 450 *kg* per *t* product; 870 – 2.720 *kg* per *Million DM* production value	Used foundry sands for disposal: 500 – 4.500 *kg* per *t* product
Application	Benchmarks/ targets for processes and companies Evaluation of minimisation efforts state of the art	Technology/company level: minimisation targets, benchmarks, control of minimisation efforts	Benchmarks/targets for processes and companies Evaluation of minimisation efforts state of the art	Technology level: benchmarks for companies; minimisation targets

2.2. Secondary-Al-smelting Industry

2.2.1. Reference AUS[45]

This study gives a broad range of ratios and factors in kg of waste per tonne of product for all wastes related directly to the secondary aluminium smelting activity. The most important processes are considered; the system boundaries are clearly defined.

The factors can be applied for benchmarking and target setting and control of prevention and minimisation measures at the company level.

At the technology level, they facilitate comparison of technologies for pre-treatment of raw materials and disposal and recovery of wastes. The comparability of different technologies for the smelting operation is not so good, as in the comparison of rotary furnaces and closed well furnaces the slag quality is not taken into account.

At the macro-economic level, the factors can be used for projections, though their broad range has to be taken into consideration. The same goes with target setting and control of prevention measures decided politically.

The application of factors in comparing different countries seems feasible, provided the different technologies and differences in raw material processed are taken into consideration.

For comparison of the waste generation in different countries, the factors have to be combined with production statistics. The market price of secondary aluminium as well as for scrap as raw material has recently been subject to strong fluctuations. For this reason, it seems important to use production numbers in tonnes of product, instead of economic reference units.

2.2.2. Reference CAT[46]

The factors elaborated cannot be considered reliable with respect to the obtained values, because raw data are not sufficient in quantity and quality. The reporting obligations in Spain are quite recent and the reporting requirements changed in 1994.

Factors have been elaborated that relate the waste generation to production as well as to material input.

Based on more and better raw data the factors will be applicable as indicators for the correlation between input quality and wastes generated.

Thus, they can be applied in the calculation of future waste arising. In combination with economic data from the scrap supplying sectors, projections on changes in waste quantity and quality due to changes in the production of the supplying sectors can be performed.

In combination with state-of-the-art factors, they can be applied for target setting and control of prevention and minimisation measures at company level, as well as at regional level.

The data is disaggregated and the waste characterisation is very detailed. This has the advantage that differences in classification in hazardous and non-hazardous waste at the international level are not a problem. These differences have to be taken into account, though, when aggregating the data.

2.2.3. Reference GER 1[47]

The waste factors given in this study represent an aggregated level, distinguishing only 'waste total', 'commercial waste similar to MSW' and 'production waste'. The latter is subdivided in 'non-hazardous production waste' and 'special (hazardous) waste'. The term 'special waste' corresponds to the definition and the respective catalogue of the German legislation, and does not correspond with the European list of hazardous wastes.

The author himself indicates that the study reflects the German situation, especially with a view to the quality of raw material applied in the process.

The comparability with factors provided in other studies is limited, as the system boundaries do not comprise pre-treatment of raw materials. This process step is not always performed in the foundry plants, but it might generate considerable amounts of different wastes and has to be taken into account when comparing data on waste generation of secondary Al-smelting plants.

As some industries of the sector perform the pre-treatment of raw materials on-site and others do not, the application of the factors for comparison of industries within the sector is limited. It would require well-specified data for each process step performed at a plant.

The raw data used for the elaboration of WF are taken from another study from 1990 (Krone[*]). Therefore it would be recommendable to make a follow up with more recent data, in order to assess the above mentioned aspects.

3.2.3. Reference GER 2[48]

The main purpose of this study is to provide factors that represent state-of-the-art technologies in order to facilitate political and management decisions on plant design. Thus, the factors are meant to be applicable at the technology level.

The raw data, on which the factors are based, were obtained from plants of one administrative district in Germany. There is no indication how many plants have been considered and which technologies they apply. There is no explanation either on how the raw data were processed. This lack of information makes it difficult to assess the transferability to other regional or national levels.

The system boundaries for the processes are not clearly defined.

In the case of secondary smelting of non-ferrous metals, especially aluminium, there is a common factor for salt slag from rotary and closed well furnaces, though the two technologies generate salt slags in different quantities and qualities. The factor for salt slags seems very low, compared to other studies. It would be important to know the methodology by which it was obtained.

Skimmings and drosses are not mentioned in this study. Though their metal content is generally recovered, the oxide residues represent a waste that has to be disposed of.

Pre-treatment of raw materials is not considered, except for oily chippings. Pre-treatment, though, generates large amounts of different wastes to be disposed of.

Due to these facts, the factors provided comprise only a part of the wastes generated by the secondary aluminium smelting activity. They therefore need complementation by other data and the respective factors.

The applicability of the factors is limited to the comparison of process-related technology and benchmarking with a view to state of the art.

[*] Krone , K et al: Ökologische Aspekte der Primär-und Sekundäraluminiumherstellung in der Bundesrepublik Deutschland; Metall, No. 6, p. 559, June 1990

Table III.2: Development of waste factors for the aluminium smelter industry – selected examples

	AUS[a]	CAT[b]	GER 1[c]	GER 2[d]
Objective	Potentials and Possibilities for the recovery of waste state of the art for treatment of wastes from Al-production	Development of WF on an exemplary basis (methodology, assessment of possibilities and limitations)	Elaboration of mass balance indicators Estimation of prevention/minimisa tion costs for specified processes	• Overview on state of the art • Comparison of different technologies
Approach	Bottom-Up	Bottom-Up	Bottom-up and top-down	Bottom-Up
Industrial Sector	Primary Al-Smelting Secondary Al-smelting	Secondary Al-Smelting	48 industrial specified processes; one example: Sec. Al-industry	Non-Fe-Metal Smelting Sec. Al-smelting
System Boundary	Al-Production Process: pre-treatment of raw material, smelting, refining, casting, waste pre-treatment/recovery/ disposal on-site and off-site	Al-Production Process: pre-treatment of raw material, smelting, refining, casting, waste pre-treatment on-site	Al-Production Process and additional environm. measures	Al-Production Process: furnace (rotary and closed well), converter, pre-treatment of chippings and skimmings
Level	Technology level (production process)	Technology level (production process)	Industrial sector	Technology level (production process)
Data Base	Literature (no primary data)	Waste declarations, inspection reports, Al-smelting plants (two plants)	Literature	Company data (anonymous)
Waste Types	Salt slags, filter dust, furnace linings, black dross	Salt slags, filter dust, furnace linings, black dross	Process output: non-hazardous waste and hazardous waste (new scrap, old scrap, chippings, skimmings/drosses, pre-molten material, furnace linings)	Salt slags, filter dust, furnace linings
Waste Factor	Waste in t per t product	Total waste amount: 410 – 720 *kg* of waste per *t* of product 300 – 590 *kg* of waste per *t* of raw material input	309 *kg* of waste per *t* of product	Salt slags: 15 -90 *kg* of waste per *t* of product Filter dust: 5 – 60 *kg* per *t* of product

[a] See Lit. 46
[b] See Lit. 47
[c] See Lit. 48
[d] See Lit. 49

Application	Company level: benchmarking, target setting, control of effectiveness for prevention/ minimisation measures, calculation of disposal costs In combination with economic data: • sector level: future waste generated in the industrial sector • macro-economic level: waste management plans, target setting, control of effectiveness of measures	Company level: benchmarking, target setting, control of effectiveness for prevention/ minimisation measures, calculation of disposal costs In combination with economic data: • sector level: future waste generated in the industrial sector • macro-economic level: waste management plans, target setting, effectiveness of prevention/ minimisation measures	Industrial sector: basis for the projection of waste generated based on economic data; Comparison between industrial sectors as well as companies	Comparison between industrial sectors as well as companies Benchmarks/targets for optimisation of material flow

SECTION IV

Glossary

Acronyms and abbreviations

ABAG	Abfallberatungsagentur Baden-Württemberg, Fellbach/D
ADEME	Agence de l'Environnement et de la Matrîse de l'Energie, Paris/F
AUS	Austria
BAT	Best Available Technology
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Bonn/D
CAS	Chemical Abstract Services
CAT	Generalitat de Catalunya, Junta de Residus, Barcelona/SP
DM	Deutsche Mark
DPSIR	Driving Force, Pressure, State, Impact, Response
EC	European Commission
ECU	European Currency Unit
EEA	European Environment Agency, Copenhagen/DK
EEC	European Economic Community
EEE	Electrical and Electronic Equipment
EMAS	Environmental Management and Auditing Scheme
ENVSTAT	Environmental Statistics
EPIS	Environmental Pressure Information System
ERM	Environmental Resources Management
ETC/W	European Topic Centre on Waste
ETSU	Trading Name of AEA Technologies plc, Harwell /UK
EU	European Union
EUROSTAT	Statistical Office of the European Community
EWC	European Waste Catalogue
FhG-ISI	Fraunhofer Gesellschaft – Institut für Systemtechnik und Innovationsforschung
GDP	Gross Domestic Product
GER	Germany
HWL	Hazardous Waste List
IHOBE	Sociedad Publica Gestion Ambiental, Bilbao/SP
inh.	Inhabitant
IPPC	Integrated Pollution, Prevention and Control Bureau, Sevilla/SP
ISO	International Standard Organisation
kg	kilogramme
LCA	Life Cycle Assessment
MEFIS	Material and Energy Flow System
MFA	Material Flow Accounting
MSW	Municipal Solid Waste
NFP	National Focal Point
NRC	National Reference Centre
OECD	Organisation for Economic Co-Operation and Development

OSW	Office of Solid Waste (part of EPA USA)
PRODCOM	Products of the European Community
PSR	Pressure, State, Response
RCRA	Resource Conversation and Recovery Act
RIVM	Rijksinstituut voor Volksgezondheid en Milieu / Netherland
t	metric tonnes
UBA	Umweltbundesamt, Berlin/D
UGR	Umweltökonomische Gesamtrechnung (National Green Accounting)
UN-DPCSD	United Nations Department for Policy Co-Ordination and Development
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WBCSD	World Business Council on Sustainable Development
WEEE	Waste from Electrical and Electronic Equipment
WF	Waste Factor

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