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Wuppertal Institute for
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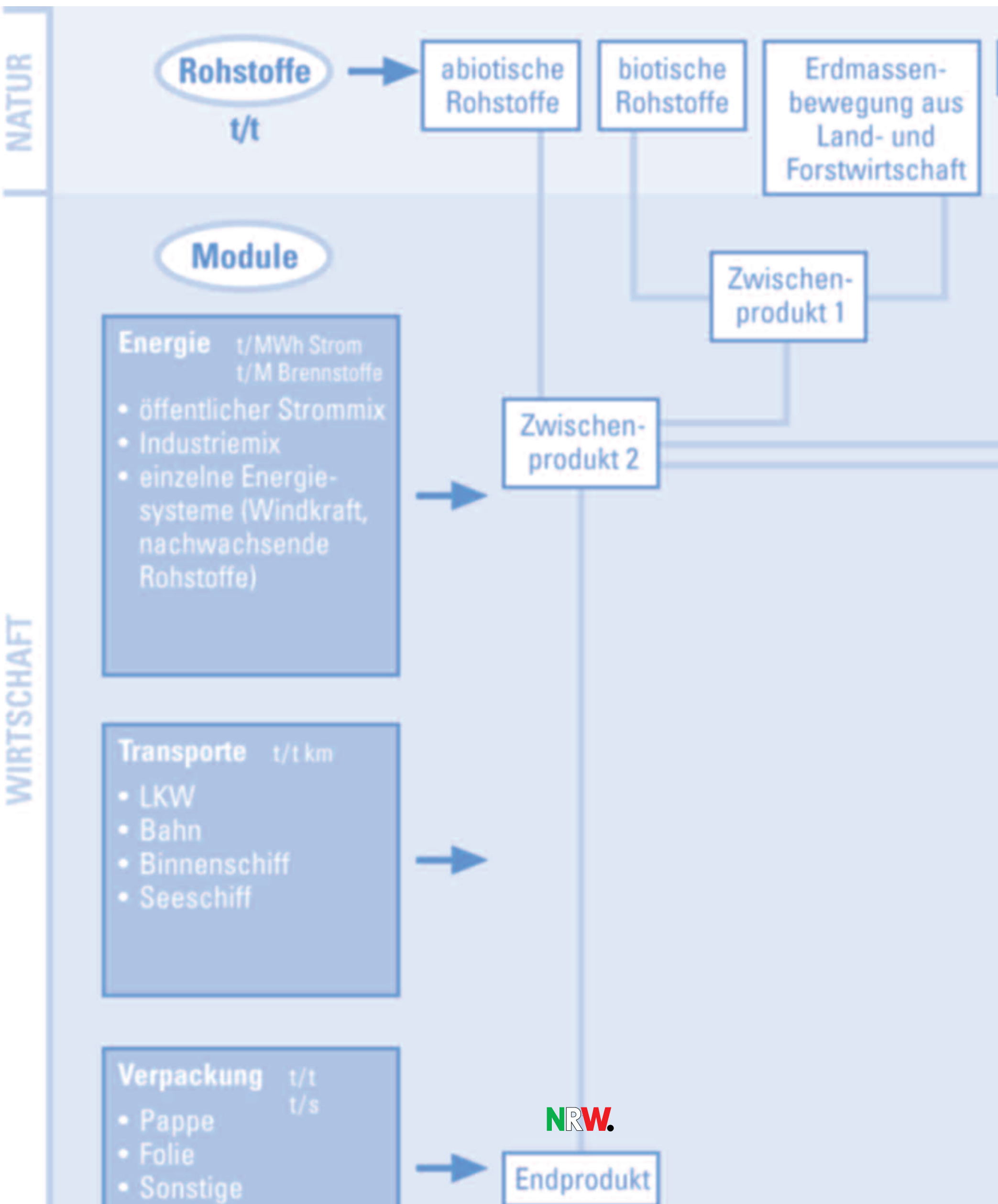
in cooperation with
Thomas Merten

Calculating MIPS

Resource productivity of products and services



WUPPERTAL SPEZIAL 27e

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at the Science Centre North Rhine-Westphalia

How to read this book:

1. Important maxims, references and explanatory examples are especially emphasised to the right and to the left and/or summarised there
2. Where indicated, praxis examples have been added to illustrate calculations.
3. Keywords are in italics. Explanations are found in the glossary.

Translation by Susan Mattern, Monika Kieslich and Jackie Sairawan (Foreword)

care
computergestützte
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All information has been identified to the best of our knowledge. However, we cannot accept any responsibility for the correctness of the information given.

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Foreword

Bill Gates once said that progress is going to come anyway – so we should make the most of it. We don't know the future of course. But we do shape it. Every day. Companies prepared to take a risk play a leading role here. In doing this they often encounter the borders set by society, for example because people do not always like new products and services. And also borders which the state establishes, thus influencing the driving forces of the market economy – striving for profits and competition – either inspiring them or crippling them, either giving them the freedom to do mostly as they please or seeking to protect the weak.

And since the early 70s we know that there are also borders to consuming natural resources when shaping progress. It's true that we can influence people's tastes, habits and income, but we have however not succeeded in pushing the borders of nature to where we would like to have them.

Each one of us changes the environment every day, consciously or unconsciously, regardless of whether we are rich or poor. We do not intend to disturb nature. We behave so because within the context of our economy it's worth behaving so. And this is not because the market economy as such leads us astray, but because the outmoded framework conditions of our economy lead to false price signals and tolerate massive subsidies, which reward the consumption of natural resources. Labour in Germany is much too expensive because it is being "milked" as a source of revenue and because resources are, almost without exception, so cheap that full-cost-pricing is out of the question. And who likes to save on things, which are cheap? The economy will become sustainable when it creates use for everyone within the framework of natural borders. To these borders belongs in particular the most economical consumption possible of natural resources. This is for two reasons. First of all, the waste and emissions of our economy are the reason for the climate acting abnormally even today, leading to natural disasters costing more than 150 billion Euros per year. The worldwide trend is to take the risk every day of more costs for repairs and more dangers to people caused by flooding, storms and the spreading of deserts. Secondly, we would need more than two planet Earth's for providing resources if the type of wealth enjoyed by the western world would be available to all people on Earth. The global trend today is to run into this trap with our eyes wide open.

What can we do? A good step would be to heed once again the wise old saying that profits can be increased when the input of production factors is kept as low as possible. This is also true for natural resources, even if the price of these is far removed from full-cost-pricing. According to a new study from A.D. Little, Germany could save 25% natural resources without any loss of quality, which would mean savings of 5,000 Euros per household every year and 700,000 new jobs for Germany. New taxes would then become unnecessary because the state would have far more income than it today attempts to have with the help of taxes.

The economy should thus first of all be dematerialised for economic reasons. However, such a development is not possible for management without a unit of measurement. For this reason 10 years ago I invented MIPS – Material Input from nature Per Service (or use) unit – as a measure for intelligent management. I hit upon this idea at that time because I was worried about the stability of the environment. And I also recognised – and this is true today more than ever – that this stability can only be guaranteed if we dematerialise the western style of wealth by at least a Factor 10. However, at today's prices for work and material, and considering today's subsidies and standards, this is not profitable. For this reason an undeterred group has been demanding for years that the economic framework conditions be adapted as necessary. Otherwise sustainability can definitely not be achieved. From the point of view of classical engineering, Factor 10 at first glance looks almost absurd. But it is not. And this is for two reasons.

First of all, it does not mean making existing goods and machines ten times smaller while giving the same performance (although even this is sometimes possible), but rather fulfilling the desired utilisation with new technical solutions. This has been obvious to us for a long time for increasing labour productivity, and the technical achievements in this area far exceed a Factor 10. Secondly, when measuring the inputs of natural resources, all materials used to obtain original materials such as copper, must be considered from the first dig of the spade onwards. I called this the ecological rucksack factor. With copper this weighs 500 kg/kg, with aluminium 85 and with steel between 5 and 25 kg/kg. Every kilogram of copper saved means that 500 kg of nature is left at its original setting. But this also means that the selection of original materials when designing artefacts, taking each one's rucksack factors into consideration, can contribute much more to increasing resource productivity than the saving of weight shows.

Japan has long since recognised the economic importance of MIPS, Factor 4 and Factor 10 as well as ecological rucksacks, and included these in 2001 in its economic strategy. For this I received together with Ernst Ulrich von Weizsäcker in 2001 the "World Environment Award" of the Japanese Takeda Foundation. This award was intentionally established as the "Nobel Prize for Environment". In Europe, too, and in the United Nations there is now some movement underway.

Enterprises in Germany should for the sake of their own future answer the following question: who or which country will in the not so distant future be able to successfully serve the world market in view of the fact that natural resources are becoming scarcer and scarcer and that those we use will undoubtedly lead to environmental changes with subsequent costs?

This manual was written by Christa Liedtke and her staff and is available in German and English. In clear language, it leads those interested step by step through the process of innovating new technical solutions using the MIPS concept.

The first step is the hardest. This also and especially applies to the attempt to convince producers and consumers that it is possible, necessary and also profitable for the benefit of mankind to shape progress within the natural guardrails – making the most of progress. Christa and her staff have genuinely earned gratitude, recognition and further major success.

Professor Friedrich Schmidt-Bleek
Factor 10 Institute
Carnoules, Provence, October 2002

Word of thanks

This handbook was made possible by the intensive co-operation of several enterprises (e.g. Kambium Möbelwerkstatt GmbH, Hess Natur Textilien GmbH, Eurotec Pazen GmbH) and institutions (Ministry for the Environment, Agriculture and Consumer Protection of North Rhine-Westphalia, (MUNLV), the Federal Ministry of Education and Research, BMBF, Factor 10 Innovation Network, etc.) during the past 8 years. The first version of the publication was developed within the project, "Act for the world tomorrow- Resource management at Hess-Natur, by Hess Natur Textilien GmbH: our particular thanks go to Mrs. Katharina Paulitsch and Mr. Roland Sturm.

Our thanks also go to our colleagues from the Material Flows and Structural Change Division and from the Working Group on Eco-efficiency and Sustainable Enterprises at the Wuppertal Institute, all of whom in recent years have worked at and with the MIPS concept. They have all contributed in their many ways to the creation of this publication. Particular thanks go to Hartmut Stiller who accompanied the development of this manual during many discussions, and to Stefan Bringezu for his very constructive corrections.

Last but not least, and not to be forgotten, are the diploma students, Ph.D. students and student trainees who made calculations according to the MIPS guidelines, and whose queries and problems contributed to a higher degree of comprehensibility and application of this publication.

Introduction

This manual sets out to be an instruction guide for the implementation of analyses according to the MIPS concept. MIPS stands for **M**aterial **I**nput **P**er **S**ervice unit, a measure developed at the Wuppertal Institute, which serves as an indicator of precautionary environmental protection.

This publication is not however a comprehensive description of the methods used, but should rather be seen as supplementing existing publications, in particular, the MAIA Handbook. Those interested in the theoretical basis of MIPS will need to refer to additional, explanatory literature (see Literature)

This practical guide contains additional information, which cannot be part of a methodological description, but which is indispensable for the practical work, e.g. reference to possible problems, which the user may encounter whilst implementing a MIPS analysis, and possible solutions according to the method.

Some of what is mentioned may seem to be dispensable or unnecessary. However, our experience shows that elements that are often taken for granted still need to be recalled.

MIPS can be applied on several levels e.g. for products and services, enterprises, households, regions and national economies.

This manual is directed at enterprises and persons, who wish to carry out MIPS or material analysis in relation to products or services. We hope that this publication will contribute to more such calculations and instigate constructive forms of optimisation, thus contributing towards the conservation of the environment and natural resources.

This manual gives a general impression of what MIPS is, and how MIPS is calculated.

Basic terms and ways of approach will be explained in the following sections, with examples and additional advice.

Concurrently we will attempt to provide a certain amount of supplementary information, e.g. conversion tables, which are often very useful.

The MIPS concept

MIPS in short

MIPS = Material Input per Service unit = MI/S

Reciprocal of MIPS = resource productivity ≙ S/MI

MIPS means **M**aterial **I**nput **P**er **S**ervice unit. In order to estimate the input orientated impact on the environment caused by the manufacture or services of a product, MIPS indicates the quantity of resources (known as "material" in the MIPS concept) used for this product or service. Once one has the reciprocal, a statement can be made about resource productivity, i.e. it can be calculated how much use can be obtained from a certain amount of "nature".

Material extractions and *emissions* cause changes in natural *material flows* and *cycles*. Previously stable cycle systems become unstable (see greenhouse effect). This drastically and/or permanently alters conditions in the environment.

MIPS – as a targeted and practicable indicator - helps to show up the positive as well as the financial potential of a resource-conserving entrepreneurship (use- and service management, cost- and resource-efficiency). By using the MIPS concept this sustainable entrepreneurship can be realised on the company level, as well as outside of it branch wide, in all areas of business economy, on a regional, national and global level. By interlocking the processes on all these levels, optimisation of all material inputs contributes to an increase in resource productivity *life-cycle-wide* or in terms of the overall economy.

MIPS calculates the use of resources from the point of their extraction from nature: all data corresponds to the amount of moved tons in nature, thus to the categories of biotic or renewable raw material, abiotic or non renewable raw material, water, air and *earth movement* in agriculture and silviculture (incl. erosion). All material consumption during manufacture, use and recycling or disposal is calculated back to resource consumption. This is done by simple calculation factors for energy consumption or also for transport, which are expressed in t/MWh or t/tkm. Complex system analyses are concealed there, which, for example, indicate resource consumption per *energy carrier* and type of power plant. This simplifies the projection and still remains targeted. MIPS thus becomes practicable and comprehensible and harmonised.

By means of MIPS, enterprises can undertake up-to-date life-cycle-wide environmental observations of their products and services. In addition, MIPS provides the distinct advantage that potentials for product- and process innovations deduced from the analyses and calculations, can be kept and applied to current and future markets. The crucial difference to those indicators that relate to outputs (emissions) is the active orientation towards sustainable products and services, and not only the reduction of emissions caused by existing products and product families.

Usable indicators for determining relevant potential of environmental impact must satisfy the following requirements:

- They must be scientifically founded.
- They must guarantee transparent and reproducible estimates of potential of environmental impact for all processes, goods and services, from cradle to grave.
- They must be easy to apply in practical use, as well as being time and cost efficient.
- They must give targeted answers.
- They must practically and conceptionally, be relevant to the economy and to profitability aspects.
- They must be applicable on all levels: locally, regionally and globally.

Indirectly MIPS says more

Sooner or later, all material input becomes an *output*: *waste* or emission. If every *input* becomes an output anyway, then by measuring the input, one can arrive at an estimation of the environmental impact potential. Most methods of evaluating the ecological quality of a product investigate a variety of outputs (emissions) whose relevance is known, or at least partially described. Compared to the multitude of emitted substances (some hundred thousand to a million), the number of substances, which have been thoroughly and comprehensively researched to their effect, is, however, miniscule (a few hundred).

However, if we look at the inputs, then the outputs (quantitative) are automatically included in the calculation. Through processes, inputs become outputs – but, unfortunately, only very few of the outputs are usable or desired (only the products). By measuring the inputs, we may not arrive at a (qualitative) impact assessment, but at a valuable (quantitative) indicator of the potential for environmental impact of a product or service. Thus MIPS is suitable as an indicator of precautionary environmental protection, and fills a gap, which other ecological estimation systems omit. MIPS is unspecific to particular materials and substance specific hazards, is precautionary and, through a reduction of material flows, is directed at the known as well as the yet unknown, environmental problems.

Life-cycle-wide observations

The same applies to MIPS as to any other form of ecological assessment: in order to be meaningful, it has to be carried out life-cycle-wide. All phases of a product have to be examined here, i.e.:

- Production (including the extraction of raw materials, the manufacturing of *pre-products*, transport and sales);
- Use (including all consumption, transport and repairs) and
- Recycling and/or disposal.

This extensive examination of the life cycle of a product is necessary, as it is not always apparent what environmental impact has occurred during manufacture, and what impact is connected with the use of a product. The products carry with them an invisible *"ecological rucksack"*, i.e. according to the MIPS concept, their environmental effects.

Objection:
The life-cycle-wide investigation is too expensive and too time-consuming.

Answer:
The effects and measures, as well as the stimulus towards product and process innovation strengthen the economy, and often surpass the investment by far.

Through MIPS an attempt is made to demonstrate these aspects and in this way to arrive at a comprehensive view of life-cycle-wide resource consumption. MIPS calculates life-cycle-wide and worldwide, and in this way the "exported" incursions in the environment are brought to light. The MIPS concept is based on the opinion that the environmental impact potential of a product can be assessed on the basis of the life-cycle-wide material input: The fewer raw materials used, the less environmental impact ensues.

Below are some explanations illustrating life-cycle-wide examinations (to the right, some examples):

- Similar products are often produced quite differently and thus cause quite different environmental impact. The individual life cycles are not independent of each other. When optimising a system, one must be aware that changes in one place can cause changes in other places. A more efficient production is of no use if the life span of a product or service is reduced or maintenance thereof is increased. The aim must always be the best solution, overall. A producer/supplier also influences the use of a product (Examples **A**, **B**, **D**, **E**).
- The significance of individual life-cycle phases can vary from product to product. There are products, which are material-intensive at the production level; i.e. the most environmental exploitation occurs during manufacture and there are products, which are material-intensive during use (Example **B**).
- From time to time, it is worth comparing solutions, where one variant is use-intensive, and the other production-intensive (Example **C**).
- The significance of the individual phases can change during the development of a product, or can even be reversed. When working at optimising only one phase of a life cycle, it may not be noticed that, in the meantime, another phase has become more significant (Examples **B**, **E**).
- In many cases not all life-cycle phases take place in the same region. This means that we are often only aware of the environmental problems that directly affect us. Processes and products are then often optimised on the basis of (limited) subjective observations. Preceding problems are often exported and then never registered or recorded again, or if so, in a distorted fashion (Example **D**).
- The most relevant areas are not always recognised (Example **E**).

Life-cycle-wide observations

A) Soda is sold both as synthetic soda (Solvay process) as well as natural soda (soda lakes). Both types of soda have different material intensities, but the same properties of use.

B) The greatest impact on the environment from cars still occurs during the use-phase. However, with reduced fuel use and increased complexity of the vehicles, the relationship between manufacture and use is changing. Manufacturing gains in importance.

C) In order to achieve a pleasant room climate, one can either heat or improve insulation. Insulation is production-intensive (high use of resources during manufacture); heating is more use-intensive (higher consumption during use).

D) Shifting the manufacture of mass goods or/ basic substances and the allied environmental effects from industrial countries to developing and emerging countries, e.g. manufacture of metal and leather goods.

E) It is a well-known fact that the laundering (and more and more also drying in the tumble-dryer) of textiles causes high environmental impact. But the equally high or even higher resource consumption during manufacture, and all along the global production line, often remains unknown to the consumer.

The measure "Service unit":

We need a measure like this when, for instance, we use rail-bound vehicles – the Regional Express, Intercity, or Intercity Express – in order to cover the distance between, for example, Cologne and Wuppertal. "Passenger transport between Cologne and Wuppertal" is taken here as the main Service unit. In this way, the various means of transport can be compared with each other. Even if the "use" can be regarded as very similar, when seen specifically and especially subjectively, it can be very different, e.g. one only has to think of the business-class compartments which can be reserved in the ICE 3. Regardless of the subjective differences in human needs, a comparison on the level of passenger kilometres is sufficiently abstract for most uses. Consumers can integrate additional factors into their personal choices and preferences, e.g. legroom, occupation quota, etc.

Service unit

When comparing different variants of a solution, it is necessary to establish a measure of comparison. According to the MIPS concept, this measure is called a *Service unit*. By using a Service unit it is possible to make a comparison between the material and "non-material" fulfilment of a service.

The difference between MIPS, MIT and MI

In some cases it is enough to calculate the MI values, instead of the MIPS values, derived from a particular use. If one wishes, for example, to compare various material alternatives, the Material Input (MI) for the manufacture of one ton initially gives adequate information. Material input in relation to weight unit is then called *Material Intensity* (MIT). Material Intensities can also be calculated, for example, for energy carriers, electricity or transport possibilities (see MI factors): they are then not given in units [t/t] or [kg/kg], but, for example, in [kg/MWh] or [kg/tkm (*tonkilometer*)].

If these material intensities are then applied, for example, to the comparison of two transmission pylons, one of wood and one of steel, they become MIPS values, derived from the material intensities through the relation to the Service unit (in this case, "the holding of a power cable above the ground for a certain period of time in a prescribed way").

System boundaries and cut-off criteria

MIPS = Material Input per Service unit

$$= \frac{MI}{S}$$

MI = Material Input (sum of the used resources)

MIT = Material Intensity (Material Input in relation to e.g. a weight, energy or transport unit)

It is advisable to record the units in order to be able to clearly differentiate between MI, MIT and MIPS.

System boundaries

When carrying out an analysis according to the MIPS concept, all technically caused movements of materials in the ecosphere are examined. All materials are counted, which are removed by human beings from their *natural deposits.*

With this we draw a system boundary between the *ecosphere* – the natural environment - and the *technosphere*, which encompasses all human activities. The technosphere is entrenched in the ecosphere and exchanges materials with it. On the one hand resources flow into the technosphere, upon which we build our prosperity. We speak here of Input. On the other hand these resources are then returned, sooner or later, back to nature in the same form or in the form of overburden, waste, emissions, *waste water* (Output).

The system boundary between the ecosphere and the technosphere is – theoretically - the only one for comprehensive life-cycle analysis, as all movement of materials from the ecosphere into the technosphere must be accounted for. However, so-called cut-off criteria are necessary for the delimitation of the work.

Cut-off criteria

In the course of the MIPS analysis, all use of resources, caused by the investigated product, or by its use should be examined. This examination is very extensive as the *pre-process-chains* can be very long and branched. Therefore, it is necessary not only to differentiate between the ecosphere and the technosphere, but also between the examined product cycle and the rest of the technosphere. That means, *process chains*, which are irrelevant to the ecological evaluation of the investigated product (e.g. the ship and its production for the transport of wool to Germany, as the ship is used so often that the material flows caused per transport of goods are scarcely worth mentioning). Thus a second differentiation is necessary: cut-off criteria. These are established under practical and methodological viewpoints. By establishing cut-off criteria, certain pre-process-chains need not be considered: those processes, which have negligible influence on the final result. It **could** be e.g. (the *production technologies*, the *production buildings* or even the production of *auxiliary and operating materials*. Some material flows within a system or *process* can be so small, for example, that they can be ignored. From what point onwards this can be the case, is determined by the cut-off criteria. Cut-off criteria should be well and carefully considered, and then roughly estimated so that none of the essential resources remain unconsidered. It is important to document system boundaries and cut-off criteria, and to draw uniform comparisons. (same depth of investigation).

An example of the complexity of systems:

For the manufacture of a pullover, wool has to be transported to Germany from Australia, for which a freighter is necessary, which is made of steel, which was produced in a steelworks. These steelworks have to be constructed, for which building materials are extracted from quarries or dredging lakes, which again necessitates tools and equipment made from steel… (Here it becomes apparent that any system can become complex. It is therefore crucial that only the relevant system elements of a product or service are investigated. What is "relevant" depends, amongst other things, upon the specific material flows, but also upon the aims/objectives -see 'cut-off criteria'.)

MI categories

In the MIPS concept, the material inputs are divided into five different input categories. These five categories are:

- abiotic raw materials
- biotic raw materials
- earth movements in agriculture and silviculture (mechanical earth movement or erosion)
- water and
- air.

The division into these five categories came into being over a period of several years of research and implementation of the MIPS concept and is practised fairly uniformly. National and international statistics increasingly use these categories for the accounting of material flows, so that the information systems fit together on the macro- as well as the micro-levels.

By differentiating between the inputs in the stated categories, the classic separation of earth, water and air can be taken into account. Earth, as a resource, is further divided into three single categories in the MIPS concept in order to attain more meaningful results: abiotic raw materials, biotic raw materials and earth movements.

The category "earth movements in agriculture and silviculture" is documented separately, in order to indicate on the one hand, the consumption (erosion) and, on the other hand the alteration of the earth through farming and forestry (mechanical earth movement) — also without extraction of resources.

As a rule, data on erosion can be made available and it is known that the extent of erosion has reached a severe magnitude. (see the example of the T-shirt on page 29). On the other hand it is difficult at present to estimate the extent of active earth movements (ploughing of fields) in a clear-cut manner — although, it can by no means be considered "environmentally neutral".

The aim is to acquire as much meaningful information as possible, for both types of earth movements.

The five categories encompass the following inputs in detail:

I. Abiotic raw materials

- mineral raw materials (used extraction of raw materials, such as ores, sand, gravel, slate, granite)
- fossil energy carriers (amongst others coal, petroleum oil, petroleum gas) unused extraction (overburden, gangue etc.)
- soil excavation (e.g. excavation of earth or sediment)

II. Biotic raw material

- plant biomass from cultivation
- biomass from uncultivated areas (plants, animals etc.)

(Domesticated animals are already part of the technosphere, and are therefore referred back to biomass taken directly from nature, e.g. plant or animal fodder.)

III. Earth movement in agriculture and silviculture

- mechanical earth movement or
- erosion

IV. Water

(separated according to processing and cooling water)

- surface water
- ground water
- deep ground water (subterranean)

V. Air

- combustion
- chemical transformation
- physical transformation (aggregate state)

MI factors

Before beginning the detailed calculations, check first whether the appropriate MI factors are not already available.

See: www.mips-online.info

Not everything has to be recalculated. *MI factors* make the work easy! Since the development of the MIPS concept, scientists, enterprises, consultants, trainers, students and apprentices have been busy with the calculation of the MI factors for substances and *modules*. These MI factors, as far as they are verified and released by the Wuppertal Institute, can be found on the homepage of the Wuppertal Institute, and are continually being brought up to date and expanded. A list of MI factors is not printed here, as it would not stay up to date. Links to further sources for MI factors can also be found on the said homepage.

MI factors can always be applied for MIPS calculations wherever generally used materials (e.g. steel, aluminium, cement, synthetic materials, glass, etc.) or so-called modules are included (electricity, transport etc.). This has the great advantage that not every pre-process-chain (e.g. pre-process -chain of steel) needs to be recalculated by each user. The application of the MI factors is however limited, as the data is not valid for every situation. Thus, for instance, the module "energy" contains the MI values for power generation, considering various energy carriers and generation systems. If special process chains need to be taken into account (power supply through supplier XY), then MI factors are generally not available to the public in databases or publications. They have to be calculated separately.

MI factors for electric power are, for example:

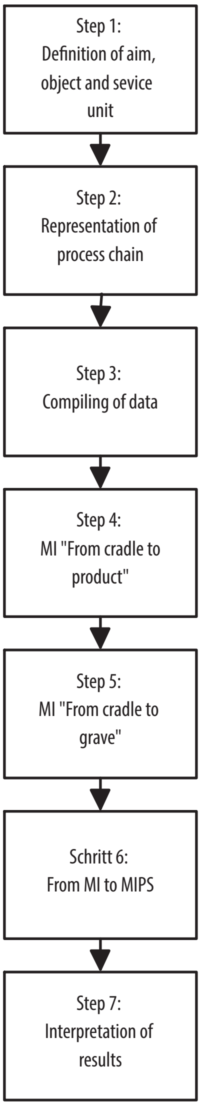
	Abiotic Resources [t/MWh]	Biotic Resources [t/MWh]	Water [t/MWh]	Air [t/MWh]	Earth movements [t/MWh]
Electric power (public supply, FRG)	4.7	–	83.1	0.6	–
Electric power (industrial generation, FRG)	2.67	–	37.9	0.64	–
Electric power (European OECD-countries)	1.58	–	63.8	0.425	–

MI factors for electric power according to energy carriers (related to FRG) are, for example:

Electric power from	Abiotic Resources [t/MWh]	Biotic Resources [t/MWh]	Water [t/MWh]	Air [t/MWh]	Earth movements [t/MWh
Nuclear power	0.31	–	79.5	0.005	–
Lignite	14	–	88.2	1.13	–
Home hard coal	0.77	–	80.3	0.81	–
Natural gas	0.32	–	79.4	0.847	–
Running water	0.13	–	0.1	0.005	–

The calculation of the MI factor is made in the same way as the following described calculation of the Material input of products and services – only that here, for example, the weight or volume unit of the material/substance, or the *calorific value* of the energy carrier is used as the Service unit. MI factors can be calculated for an unlimited number of substances and modules, and are prepared in lists. In fact, every single MIPS analysis contains a multitude of such MI factors (MI factors of the various substances used can be calculated through process orientated data gathering).

MIPS Calculation in seven steps



The calculation of MIPS proceeds in seven steps. These steps are basically independent of whether the calculations are made manually or with the help of an appropriate computer programme.

The starting point of the analysis/calculation is defining the aims, the objects under view and the basic underlying Service unit (Step 1) to which all numerical values will be referred. This is the basis for the comparison of the various products/services. Subsequently, the life cycle of the product at issue is represented as a process chain (Step 2), which shows the individual steps of the process, in relation to each other. This step serves the structuring of the calculation. Hereafter, the inputs, and as far as necessary, the outputs, are gathered and preserved in a *process picture* (Step 3). A *data-sheet* is used for recording information, in order to guarantee uniform progress, and to document the data gathered. On the basis of this information, the Material Input is calculated "from cradle to product" (Step 4) by linking the gathered data with the MI factors, provided that they are available. Consequently, the Material Input is then calculated "from cradle to grave" (Step 5).

At this point, data from the life-cycle phases of "use" and "recycling/ disposal" contributes towards the whole picture. This differentiation makes sense for several reasons:

- the producer generally determines the manufacture of goods,
- the period of use can often be influenced individually by the customer,
- recycling and waste disposal can be very different, and often completely unknown, for today's new products,
- analyses are often separated into "production" and "use".

However, the manufacturer can exercise a great influence on the use phase of a product by determining certain properties of a product (e.g. the amount of electricity needed for running a refrigerator).

After the Material Input has been calculated "from the cradle to the grave", the Material Input Per Service unit (MIPS) can be calculated (Step 6). When the Material Input Per Service unit has been calculated, an interpretation of the results can then be made in the final step (Step 7).

MI/MIT calculation instead of MIPS calculation:

Should one only need to calculate the Material Input of substances or modules or semi-finished products, then certain aspects in the respective steps can be completely omitted (e.g. definition of Service unit, Steps 5 and 6).

Use of auditing software

Given sufficient time, the MIPS can be calculated by using only a sharp pencil and a couple of sheets of paper. However, in the interest of the user, a spreadsheet at least should be used. ECO-auditing programmes, i.e. programmes, which are especially designed for carrying out eco-auditing and material-flow analyses, can be used partly for carrying out MIPS analyses. Many of these programmes improve the overall picture of a project and guarantee a consistent flow of data. They integrate a variety of helpful and necessary functions into a programme. Therefore, they are often a prerequisite for carrying out a time and cost-efficient analysis. In our experience, the initial effort put into training and acquisition stands in direct proportion to the greater aims and results. The following programmes have been thoroughly reviewed and are to our view suitable: GaBi® from the Institut für Kunststoffprüfung und Kunststoffkunde (IKP) from the University of Stuttgart and PE Product Engineering GmbH, and Umberto® from ifeu (Institut für Energie- und Umweltforschung, Heidelberg) and ifu (Institut für Umweltinformatik, Hamburg).

This list is not final. There are several other software systems about ecological assessment on the market. They should be checked by each user according to each individual criterion.

Step 1: Definition of the aims, objects and the Service unit

What is a "Service"?
A service in the textile branch can, for instance, be "clean laundry". This service can be provided by a washing machine, washing by hand, or an innovative invention (e.g. using new textiles, combined with new cleansing products or processes).

"Service" of intermediary products
If two cars are to be compared and the Service unit [Pkm] is agreed upon, then there is no point in referring the production of the car battery to this Service unit. The Material Input per battery [kg/battery] is, however, necessary when analysing the production and use phase of a motorcar. Furthermore, car batteries can be used for many other things, e.g. electric fences.

"Service" of complex end products
A motorcar can be used, for example, as a stationary advertisement, as a private vehicle, as a crash-test vehicle or as a taxi. Different results can be deduced from the manner of use for each life-cycle phase relative to the specific Service units. Thus, whilst a stationary car has almost no wear and tear, a taxi on the other hand does.

"Service" of disposable goods
In general, disposable goods usually have a clearly defined and short life. The definition of the Service unit is also relatively simple; e.g. the purpose of a throwaway plastic beaker is to have a beverage, ready to drink, immediately. Afterwards, the beaker is then disposed of.

At the beginning of the MIPS calculation, it must be clear what the objectives are. The aim of the analysis and evaluation must be clearly defined, as well as the objects under scrutiny. Generally a differentiation must be made between a comparison of one or more objects, of a single object analysis, or of optimising production or of the use of the objects. The aim of the analysis and objects under analysis influence to a greater extent the system boundaries open to choice, but also the financial budget and human resources available for the implementation. In other words: when one's budget is known, the extent of the analysis to be carried out with it should be carefully considered, i.e. how cost/use elements stand in proportion to one another.

In most cases, but above all in order to make a comparison of various products, a unit of measurement must be set initially to which all data can then be related. In the MIPS concept, this measure is called a Service unit and specifies, which use a particular product provides. In addition, the Service unit should also throw light on non-material product alternatives and innovative services. The establishment of a Service unit compels one to consider whether, how and which different things are to be compared.

When calculating the intermediary steps and results, it is generally wise to not yet refer to this Service unit, but to refer to weight units. For example, strictly speaking an *intermediary product* (as a rule so-called semi-finished products such as sheet-steel or a part of a facade, etc.) does not yet fulfil a service, and its use in the end product can still be open (sheet-steel can be part of a car, a house or a toy, etc., or not included in the product at all, but categorised as "production waste").

But why do we need a specific measurement of comparison at all if we only want to compare two simple things quickly with each other? Quite simply: because even "similar" goods can provide different uses.

Were transport systems to be examined, then *passenger kilometres* (Pkm) could, with some reservations, be selected as a specific measurement of comparison for different vehicles. We would then see that a private car per Pkm is cheaper than a truck (of course, a truck is not built for passengers, but many small trucks can if required be used for passenger transport). However, if we change the Service unit and consider the tonkilometre (tkm), then it is quickly obvious that a truck is cheaper than a car (of course, a car is not built for…).

The results of such comparisons can be completely different – with the same objects of comparison! There can be no clear-cut answer to the question: is A better than B? The answer to the question must be as follows: assuming that under XY circumstances and conditions A is better than B, under other circumstances and conditions B can be better than A. Thus it is of utmost importance that the Service unit is specified and explained.

The following rules must be considered when determining a Service unit:

- A Service unit should enable many different product alternatives to be compared. Therefore, it should be formulated in as general terms as possible.
- The Service unit should reflect all the important aspects of the use of a product.

A compromise must be found between both of these aspects. It is hardly possible that both criteria can be completely fulfilled. This is because the use that even a simple product provides can be too complex to describe easily, and also that the variety of solutions are manifold and very different (and thus not identical in all aspects of use).

Therefore, every comparison unit must be restricted to the central properties and uses of each individual product. Other aspects (e.g. aesthetics, portability, ergonomics, individual preferences) are important and must be taken into account before decisions are made. These cannot however be the basis of a limited ecological assessment.

Nevertheless, it makes sense to make comparisons as they highlight the strengths and weaknesses of products. One must delve in order to find out necessary and perhaps also less important properties of certain products. Thus not only are our powers of discernment enhanced, we also learn to understand our own products better and also to discover new alternatives.

It can be a lot simpler where standardised products are under review (e.g. standardised rolling bearings, screws, materials, etc.). Where such standards are concerned, very detailed demands and conditions are often stipulated. In construction, only these properties are taken into account so that any possible "overfulfilment" does not have to be considered. Not defining a Service unit only makes sense under certain conditions:

- if there is only one intermediary and unserviceable product to be calculated (e.g. a substance, or semi-finished product);
- when products do not need to be compared, but "only" the process chain needs to be optimised (e.g. cement production);
- if the products to be compared serve the same purpose (e.g. two throwaway beakers).

Outcome of Step 1

The Service unit of comparison is determined as a result of this step. For example, to be clothed with a white T-shirt for one wearing cycle. A wearing cycle consists of, e.g. two days' use, and the subsequent washing and ironing.

Product comparisons can give completely different results depending on the specific or supposed use as unit of measurement.
Identical products can with low-use intensity have a comparatively high MIPS value, and in the case of high-use intensity have a low use of resources — or the other way round.

A possible way to define the service of a built-in kitchen:

The storage space of a standard kitchen, according to DIN 18022, was calculated at 2,061 litres.
A life span of 50 years was estimated for the solid wood kitchen, and 20 years for the fibreboard kitchen. One litre storage space/year can be defined as a Service unit.
But the Service unit of the kitchen could also be divided into the following categories:

- storage of supplies
- food preparation and cooking
- boiling, roasting, frying, keeping warm
- serving
- eating
- cleaning, washing up
- garbage disposal.

A rundown of Service units here is inordinately complex.

Practical examples

Service unit of clothing…

"To be clothed for a certain period of time" could be defined as the smallest common denominator when describing the "service" of clothing. This "being clothed" not only describes "protection" as the basic use of clothing, but also includes "well-being" and "self-expression". "Person-year" could be taken as a measure for comparison.

On the basis of this, the expenditure for clothing can be recorded and compared.

Often, it is not necessary to ascertain the complete clothing expenditure, but only to carry out comparisons of the products. One "classic" question in connection with clothing and textiles could be: Are natural fibres more environmentally friendly than synthetics? Or, "Seen from the whole manufacturing process, is a cotton pullover more resource-efficient than one made of pure wool?". Point of reference in a comparison can be the complete expenditure of energy/resources per wearing-time. Here, for example, the measure for comparison, "pullover-year", could be introduced. The service provided would need to be defined in several steps. "To be clothed with top clothing, in winter, outdoors, in casual situations, for a certain period of time."

… and printing cartridges

Here, the common denominator can be defined as "the writing of text" or "drawing of pictures" in a certain quantity. Cartridges contain different amounts, function in different ways, but because of the number of printed norm-pages, they are easily compared with one another. As printing cartridges generally do not fulfil any aesthetic or other functions, the Service unit is relatively simple. And if one does not believe the manufacturer's claims about the capacity of the cartridges, it is relatively simple to test it out oneself.

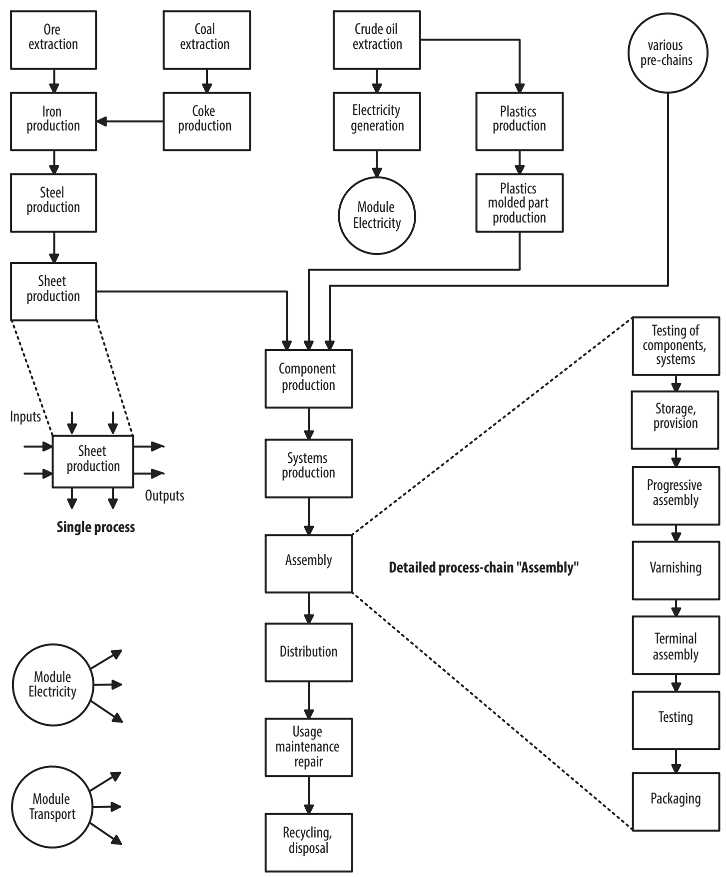
Step 2: Representation of the process chain

In order to give structure to the evaluation, a diagram is made of the life cycle of the product or service under scrutiny. Ideally, all processes are represented in this diagram, which are necessary for the manufacture, use and disposal of the product in question. In this way, an overall picture can be achieved of the appropriate processes. Gaps in the information are more easily spotted. When setting out the process chain, it is advisable to select varying detailed descriptions. In this way, it is easier to retain an overall impression of the whole process and simultaneously observe individual processes in detail. However, before recording all the pre-products in the process chain, it is worthwhile checking whether these substances have not already been calculated and analysed (MI factors). An exact examination only makes sense where this has not been done previously, or it cannot be used in its present form.

Data-sheets, as well as other assistance can be found at www.mips-online.info

Outcome of Step 2

The outcome of this stage is a process chain or a system of process chains indicating which processes are necessary for the manufacture of products or the execution of a service, including the preceding processing steps.



Step 3: Compiling of data

In the third stage, the necessary data is gathered about each identified process. All data should be fully documented with source, year of reference, explanatory notes, exact amounts, units, etc. If none of the aforementioned software is used, it is advisable to use uniform data sheets.

The gathering of data (and verifying thereof) is the most important and frequently the most time-consuming step of the MIPS analysis.

Sources of information can be:

- Direct measurements: they give specific data and (mostly) reliable results.
- Interviews: they often provide firsthand, invaluable experience (interviews with and/or assessments by experts).
- Literature references: they are often the only possibility of acquiring information about procedures outside of the enterprise. Reference books, relevant periodicals and articles and specialised dictionaries can also be referred to. Data bases can be very useful in literature research.

Even so, there are often still gaps in the information, and it will be repeatedly necessary to carry out “qualified estimations”. Specialised knowledge of similar processes is necessary for estimation. Theoretical calculations can provide important data in particular where process-engineering procedures are concerned.

Incomplete information is expanded on by “qualified” estimates.

It is crucial that the source of information is precisely documented, particularly if estimation is being made.

When assessing one’s own product, care should be taken not to unrealistically over-estimate the product. In particular when comparing competitive products (or *average products*), a *minimum estimation* should be made initially, and where one’s own product is concerned, a *maximum estimation*. Even so, if one’s own product is indeed found to be better after such a comparison, a further more detailed examination of the product has to be made to be absolutely sure. For more thorough examinations, where information may be lacking, minimum as well as maximum estimates should be carried out to provide a complete range of results.

It is both helpful and useful to have several sources of information at hand. Even if one’s own test results are available, additional information such as literature and bibliographical references or one’s own specialised knowledge can all be useful, helpful and necessary to test plausibility. As it can never be completely ruled out that a miscalculation has occurred somewhere, either when gathering data or when taking measurements, or that inadequate information has been gathered, it is wise to check particularly good or particularly bad results.

In principle, every single result should be checked: even anticipated results can be incorrect.

When data deviates from literature sources, one should be able to explain this.

Note: if basic data differs considerably to that in literature references, the reason for this should be determined and the difference explained.

The investigated data (or available data) will generally be heterogeneous. Basically, there is a differentiation between general and specific data.

General data represents average values and relates to a *product classification*, e.g. white cotton T-shirt, size L. General data reflects specific branch or national averages.

Specific data, however, is only valid for the product under scrutiny and under special conditions.

A further important difference is the *scope of data*. Thus, electricity production systems for a manufacturing process in South America cannot be applied, under the same conditions, to a similar process in Germany. Similarly, recorded data should relate to the same period of time (situation and duration) in order to preclude any seasonal variations (e.g. average values of several years). In the case of agricultural products or heating energy consumption, it is necessary to include averages covering several years. If the data is available for only one year, and the product is new, it can be particularly difficult to calculate these values. One can then only refer to one year, and must indicate the limitation of this information. Better insulation in a warm winter pays off less than in a cold winter.

However, it can in principle be said that the quality of data is decisive for the quality of values, which are later calculated. When compiling data, it is worth observing several general rules:

- Material flows have to be stated in an appropriated weight-unit (kg, t, etc.).
- It is important to state the unit alongside the numeric values. Many a surprising result can be avoided in this way. Quantitative information without a unit is always wrong!
- Primary raw materials necessary in the process are first listed under Input. They are divided into five categories. These Inputs have no pre-process chain; they generally occur in those processes, which are at the beginning of the whole process chains (with the exception of combustion air and partly water). In addition, all other (non-primary) inputs are listed: Substances, sources of energy, pre-products, modules, *infrastructure*, auxiliary and operating materials. These inputs have preceding process chains and are calculated within them, or there are MI factors already available for them.
- Listed under Output are all main products and *by-products*, as well as waste, sewage, *exhaust air*, and emissions, which are released into the air, water and the earth.
- Not all inputs and outputs need to be recorded. This depends on the choice and establishment of the system boundaries and cut-off criteria. Waste, sewage, exhausts air, and emissions only need to be recorded according to the MIPS concept if they are to be further processed (e.g. in a recycling plant, or in an exhaust air purification plant) and require further material input.
- The source of data must be recorded for every material, for every form of energy, for every pre-product.
- Special information should also be recorded, e.g. additional explanations about data, data source, etc.

Data quality is decisive for the quality of the calculated results.

At the end of the investigation, it is advisable to establish how many of the material flows involved in the process chain can actually be supported by documentary evidence, and by which.

“Classical traps”:
- Quantitative information without units is always wrong!
- One can only compare comparables!
- The conversion of units can be tricky!

An Argument for SI Units (Système International d'Unité)

If conversions have been made into other units, then the original particulars should always be documented. When making conversions, it is important to ensure that the original units have been correctly interpreted. A ton does not necessarily weigh 1,000 kg; it could be an U.S. (short) ton (907.185 kg); or it may be a British (long) ton (1,016 kg). If one is working with combined units and is not sure of a certain value, then a premature end can threaten all endeavours. It is good to recall that a "billion" in, for example, the US is a "Milliarde" in, for example, Germany.

Outcome of Step 3

After this step, one has an overall picture of the material and energetic inputs and outputs of the individual processes used during the manufacturing of a product and appropriate services. By this time, a first check has been made of the acquired information in terms of conclusiveness. Gaps in the information have been recognised and resolved (at least with estimates).

Compiling of Data and Documentation with the Data Sheet

Data sheets can be used for compiling and recording information/data. (www.mips-online.info). All material and energetic inputs and outputs can be recorded in this table. Further information, such as necessary land use, can be added, although this is not part of MIPS.

The data sheet is divided into Input and Output. The individual inputs and outputs are then further divided into different data categories, contributing to the wider structuring of the data. These are the data categories for the Inputs:

- natural inputs (extracts from natural deposits):
  - abiotic raw materials
  - biotic raw materials
  - earth movements
  - water
  - air
- pre-treated, processed inputs (all previously treated raw materials):
  - basic, working and building materials
  - energy sources/carriers
  - modules
  - infrastructure
- auxiliary and operating materials

Note: Abiotic and biotic raw materials appear very rarely on the data sheets in the further processing steps, as it is primarily pre-treated materials and pre-products that are used.

Natural Inputs

Abiotic raw materials:
- All unprocessed abiotic raw materials that are taken directly from nature; e.g. ores in a mine.

Biotic raw materials:
- All vegetable raw materials taken either from cultivated or uncultivated areas and all animal raw materials from uncultivated areas. (Animals within cultivation are calculated under the addition of plant material, etc.)

Earth movements:
- All earth movement in agriculture and silviculture also ploughed ground or erosion.

Water:
- All water taken directly from nature. Here, a differentiation is made between processing and cooling water. A further differentiation is made between ground water, surface water and deep ground/ subterranean water, according to the manner of withdrawal. (Drinking water is processed water and therefore a pre-product and not listed here.)

Air:
- All directly extracted air as long as it is altered, either chemically or physically (aggregate state).

Pre-treated, processed inputs:

Basic, working and building materials:
- Substances that are used in the processes concerned and that were manufactured in a preceding process (e.g. steel, PVC, glass, chemicals).

Energy sources/carriers:
- Thermal and non-thermal converted sources/carriers of energy (e.g. firewood, oil, coal or gas).

Preproducts:
- Semi-finished products, prefabricated elements, etc., which will be applied in the process concerned and were produced in separate processes.

Modules:
- Modules can be or have been calculated for some very important and recurring services (electricity, transport, drinking water). These provide appropriate values for a greater number of uses.

Infrastructure:
- All installations, which are necessary for a process but not “consumed” (production buildings, production technologies, etc.).

Auxiliary and operating materials:
- are materials that are part of the process, but only have an auxiliary function; working materials necessary for the manufacturing process that do not enter the product.

Other:
- all inputs that cannot be classified elsewhere.

Outputs are classified under the following categories: main product, by-product, waste, sewage, exhaust air and emissions.

Sewage and exhaust air are only to be recorded if they necessitate other raw materials for further processing (e.g. disposal, filter, sewage plant). Emissions may be listed, but do not need to be.

Outputs

Main products:
- All products for which the process is chiefly operated.

By-products:
- All other commercially usable products for which the process is not chiefly operated.

Waste:
- All commercially unusable materials; to be split into: waste that has a further use, waste for recycling, and waste that needs to be disposed of.

Wastewater:
- All water that goes into the draining ditch or that goes into a sewage plant.

Exhaust air:
- All carrier gases of solid, liquid or gas-like emissions.

Emissions:
- All pollution of earth, air and water emitted by a plant or process.

Name of process

Measure for comparison / unit

Sheet for compiling data:

Data refer to:

Input		**Unit**	**Amount**	**Source**	**Year**	**Reference region**	**Reference year**	**Specific information/ explanatory notes**
Natural inputs								
A	*Abiotic raw materials*							
AA	Minerals							
AB	Energy carrier							
AC	Unused extraction							
AD	Soil excavation							
B	*Biotic raw materials*							
BA	Plant biomass from cultivation							
BB	Plant biomass not from cultivation							
BC	Animal biomass not from cultivation							
C	*Earth movements*							
CA	aktive: e.g. ploughed earth							
CB	passive: e.g. erosion							
D	*Water*							
DA	Process water							
DAA	Surface extraction							
DAB	Groundwater extraction							
DAC	Deep groundwater extraction							
DB	Cooling water							
DBA	Surface extraction							
DBB	Groundwater extraction							
DBC	Deep groundwater extraction							
E	*Air*							
EA	Combustion							
EB	Chemical conversion							
EC	Physical conversion (aggregate state)							
ED	Other extracted air							
Pre-treated/processed inputs								
F	***Basic, working and building materials***							
G	*Energy carriers*							
GA	Energy carrier (thermal conversion)							
GB	Energy carrier (non-thermal conversion)							
H	*Pre-products*							
I	*Modules*							
IA	Electricity							
IB	Transport							
IC	Drinking water							
J	*Infrastrukture*							
JA	Production buildings							
JB	Production technologies							
K	*Auxiliary and operating materials*							
KA	Auxiliary materials							
KB	Operating materials							
L	*Others*							

Information on units | *Information on input amount* | *Information on data source* | *Information on year of publishing* | *Information on reference region* | *Information on reference year*

Under A to E all direct extractions from nature are listed (natural inputs, incl. water)

Under F to L all pretreated and treated inputs are listed (materials, products, modules, etc.)

Under O to R waste, sewage, exhaust air and emissions are listed

Under M the main products and under N the by-products are listed

Output		**Unit**	**Amount**	**Source**	**Year**	**Reference region**	**Reference year**	**Specific information/ explanatory notes**
M	*Main products*							
N	*Side products*							
O	*Waste*							
OA	Waste for reuse, recovery, recycling							
OB	Waste for final disposal							
P	*Waste water*							
PA	Waste water without treatment							
PB	Treated waste water							
Q	*Exhaust air*							
QA	Exhaust air without treatment							
QB	Treated exhaust air							
R	*Emissions*							

Step 4: Calculation of the Material Input “From the cradle to the product”

In this step, the Material Input is calculated right through to the finished product. If “only” MI calculations are being made of a material, module or a semi-finished product, etc., then the following implementation is almost analogous.

The data and results compiled in Step 3 (Compiling of data) are used for these calculations. Then the respective Material Inputs (in kg) or Material Intensities (e.g. in kg/kg or kg/MJ) are determined for the respective intermediary products, depending upon the processes necessary for the direct extraction of resources.

MI factors were already calculated for a number of the processes and substances. These can be referred to if necessary. This applies in particular to energy carriers, but is, however, similar for a number of the frequently used basic, working, and building materials. A list of these values can be downloaded from the homepage (www.mips-online.info). These lists are regularly brought up to date. Prototypes of the data and *calculation sheets* can also be found at this website.

The calculation of the Material Input (MI) is arrived at by multiplying the individual input quantities by the specific Material Intensities (MIT) of the input substances. When these have been added together, one arrives at the Material Input of the relevant intermediary product. It is important to consider that whilst compiling data and calculation, one only adds up within each individual category.

Material Input = input amount x material intensity
MI = Amount x MIT.
In units:
kg = kg x kg/kg or
kg = MJ x kg/MJ or
kg = Pkm x kg/Pkm etc.

The single categories are not summed up, but listed seperately.

Material Input has the unit [kg].

Material Intensity carries the unit [kg/unit], e.g.[kg/kg], [kg/kWh], etc.

For products (intermediary products), which are handled in weight units (wool as opposed to pullover), it is advisable to give the Material Intensity as a result, i.e. Material Input per kg of the good. Where no Service unit can be defined for such products or intermediary products, it is not possible to calculate the MIPS value.

Note: the Material Intensity carries the unit [kg/kg]. The only deviation from this rule, however, is when dealing with weightless goods such as electrical power or heat, where it is then necessary to give the details of the Material Intensity in another unit, e.g. [kg/kWh]. A weight unit always appears in the numerator, and the usual unit for the product appears in the denominator.

When calculating the Material Input and the Material Intensity, the differentiation between *main products* and *by-products* can be essential. Main products can be summarised as all the products for which the process is mainly operated. The Material Input of a process is attributed to the main product, or split into the various main products according to weight shares. By-products are products which are also marketable, but for which the process is not mainly operated, perhaps because the market price is too low, or because they accumulate as surplus. The Material Input of the process is not added to by-products, only the possible additional expenditure of further processing. This classification can vary from case to case, and can depend upon other circumstances and conditions. The question of main products and by-products thus takes a central position in a MIPS analysis, and attention should be paid to it when establishing the parameters of a system.

An example:
If heat is only expelled during power production, then it is an emission; if, on the other hand, it is fed into a district-heating network, then it can be considered as a by-product (for which further processes are needed: construction and operation of the district heating network). If one constructs a small-scale cogeneration plant, primarily designed and operated to meet heat demand, then power and warmth are both main products.

Outcome of Step 4

The Material Input per Product was calculated. For a particular T-shirt, that means, for instance, resource consumption of:

• abiotic raw material	2.0	kg
• biotic material	1.2	kg
• water	1,480.0	kg
• air	12.5	kg
• erosion	223.0	kg

(2.83 kWh electricity are included).

The “ecological rucksack” of the T-shirt is then:
= MI (TMR) – net weight
= 226.2 – 0.17 kg
= 226.03 kg!

Electricity used for 1 T-shirt:

The almost 3 kWh of electricity used for the manufacture of the said T-shirt can produce very different MI values, depending on the primary energy carrier.

Thus the MI value of the T-shirt can vary between:

- 1.03 kg (real electric value from the analysed production chain) and
- ca. 40 kg (using electricity produced exclusively by brown coal).

If the T-shirt was produced entirely in Germany (FRG-mix) then the abiotic MI value would be at least 15 kg!

Practical examples

Main and by-products

Sheep are kept for various reasons:

- in Germany, sheep are kept mainly for environmental protection reasons (landscape protection), or for the maintenance of dikes. Meat is often only a by-product. Wool is mostly waste.
- in Scandinavian countries, sheep are mainly kept for meat. Wool is a by-product or waste.
- in Australia, wool as well as meat is a main product.

If a nomad from Mongolia was asked about sheep, he would probably not understand the question at all: sheep are kept of course because they provide meat, milk and wool. Domestic animals are an integral part of the Mongolian culture, and all products are used equally intensively.

Calculation of the Material Input using the calculation sheet

A calculation sheet can be used for calculating the Material Input (see page 31). Using this table, the Material Input of individual process steps is calculated for products (and thus also for intermediary products).

On this calculation sheet, as on the data sheet, the name of the process and the unit of measure are recorded. Next to this, all input substances are recorded with their input amount according to the data sheet.

For the actual calculation, the input substances or the input amounts are combined with the relevant Material Intensities of the five data categories. The data sheets consist of one column for the input amount of the respective substance and two columns for each of the five categories. The Material Intensity of the used pre-products is inserted in the first of the two columns. In the second column the contribution of the individual input substances to the Material Input of the product/process is calculated by multiplying the Material Intensity and the input amount. The addition of these individual Material Inputs results in the whole input in the respective categories.

Step 5: Calculation of the Material Inputs "From the cradle to the grave"

All processes of a production line are drawn up on a data sheet and a calculation sheet in order to calculate the system-wide Material Input of services or products. The use of resources can be summed up in life-cycle phases, and displayed separately.

The calculation of resource use right up to the complete product occurs in Step 4. The majority of products cause expenditure of resources, not only during manufacture, but also during use and disposal. These expenditures often depend upon the user, or are determined by the specific use/function of a product. Therefore, these resource expenditures should be calculated separately from the manufacture in this step.

Practical examples

Besides production expenditure of a T-shirt, the actual use of the article, through the necessary laundry, causes resource consumption. This consumption generally lies above and beyond that of manufacture. Repairs do not at present play a relevant role with most textiles, as opposed to shoes.

Outcome of Step 5

In addition to manufacturing, the expenditure of usage and disposal are calculated and included. Therefore, e.g. 100 wearing-cycles of a T-shirt -> Manufacture + 100 x washing + 100 x ironing.

- abiotic raw material 119.5 kg
- biotic raw materials 1.2 kg
- water 4,200.0 kg
- air 40.0 kg
- erosion 223.0 kg

The result arrived at is the Material Input of a product, assuming usage throughout all life-cycle phases.

Name of process (cf. process picture)

Unit of comparison, 1 kg /piece of product or specific service

Calculation sheet:

Data refer to:

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/ pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
				0.00		0.00		0.00		0.00		0.00

Fill in the name of pre-products and material used.

Informattion on units, likely in kg. For non-material products, e.g. energy also kWh or MJ.

Information on input amount (from data sheet, already calculated.

Fill in the MI factors of pre-products MI in kg/kg or kg/other unit).

Calculation of Material Input by multiplication of the Material Intensity with input amount [kg].

Calculation of overall result per category by addition of part results.

Information on other categories according to the example of abiotic material consumption.

Step 6: From Material Input to MIPS

The relation to the Service unit is achieved in this final step of the actual calculation. MIPS, i.e. Material Input Per Service unit, is reached by dividing the Material Input by the number of the Service units. MIPS has the unit [weight of moved nature / service] or [weight of moved nature / product (weight of product)]. MIPS is recorded in five different categories (abiotic raw material, biotic raw material, earth movement, water and air).

Outcome of Step 6:
The result of Step 5 is now applied to the Service unit. As a wearing-cycle was defined as a Service unit, the calculation of the MIPS value of the result of Step 5, which refers to 100 wearing cycles, has to be divided by 100.

- abiotic raw material 1.2 kg
- biotic raw material 0.01 kg
- water 42 kg
- air 0.04 kg
- erosion 2.2 kg

With this result, a comparison can be made with a T-shirt that, for example, has a life span of only 20 wearing cycles. If one takes a Service unit of, for example, “being clothed with a T-shirt for 5 years”, then it is possible to calculate specific values. A “long-life” T-shirt has only one production process, whereas a “short-life” T-shirt needs to be produced several times. The usage-expenditures “washing and ironing”, however, remain the same.

Step 7: Interpretation of the results

Subsequent to the compiling of data and the calculation of the Material Inputs, the Material Intensity or the MIPS values, the evaluation and interpretation of the results follows.

A comprehensive interpretation of the category "earth movement" is not possible at the moment. It is obvious that our methods of agriculture and silviculture, ploughing and monoculture represent a severe interference with our natural environment. This trend cannot go on and has to be reduced (e.g. the inordinately high rate of erosion in the quoted example).

When interpreting the results, it is permissible and often makes sense to compile the following categories *equally*: "abiotic raw materials", "biotic raw materials", as well as "earth movement", (but here, only "erosion"). However, a differentiation between the categories must remain possible.

The sum of these categories can be understood as a main indicator of these observations and is called "Total Material Requirement" (TMR). This indicator is used in the resource accounting of national economies.

The category "water" should likewise be examined separately, as interference with water can have very different effects and consequences regionally. Differentiating between processing and cooling water helps to avoid making the specific significance of this value unnecessarily difficult, because of the vast amounts of water necessary for cooling.

When considering the category "air", the various uses of particles are to be comprehensively summed up (combustion, chemical transformation and physical transformation). CO_2 emissions are dealt with in the section "combustion air". The category "air" should also not be summed up with others.

Concerning the significance of a comparison, one should always check what percentage of the input was actually analysed, and what was only estimated. The amount of analysed and calculated inputs should be "as large as possible".

On the particular position of the category "earth movement":

Earth movement embraces the "active" moving of earth, e.g. ploughing fields, and the "passive" movement of earth (triggered) erosion. As the availability of reliable documentation is inadequate to date, the category "earth movement" only encompasses data about erosion.

Therefore TMR is the sum of the abiotic and biotic raw materials and of erosion. This practice is valid until further notice. Current developments can be followed on the homepage.

Outcome of Step 7:

A comparison of alternatives could determine the preferred ones. Particularly material intensive process steps were sought. On the basis of these results, appropriate optimising strategies can now be selected.

Optimising Strategies

The point of a MI(PS) analysis often lies in optimising the substances used, the products under scrutiny or the services. Some possible suggestions are presented in the following illustration:

- Reduction of Material Input within the investigated process chain (process optimisation);
- Reduction of material input in a product (product optimisation);
- Increase in the Service unit, and in use (product optimisation);
- Comparison of product and service alternatives.

Optimising possibilities generally present themselves in all processes and in all life-cycle phases. Of course, optimising makes most sense where the most savings can be made ultimately. The first and most important step is to find this out and still retain an overall view of the whole life cycle: the so-called "hot spot analysis". Once the processes to be optimised are spotted and recognised, then a list of priorities can be compiled according to the extent of the potential cost and resource savings. The question then arises, which of these processes can be changed independently, which depend indirectly on others, and which ones cannot be changed, or, if so, only with difficulty. Subsequently, the processes, which are deemed capable of being optimised, are listed in the following way:

- Processes where directly responsible (e.g. internal processes of a firm).
- Processes where indirectly responsible (e.g. processes of suppliers or customers).
- Processes outside the field of influence (e.g. extraction of raw materials, power generation).

To which of these three above-mentioned categories the specific processes belong depends very much on the specific circumstances and situation. It can be, for example, that an internal process in the automobile supply industry does not allow for scope of action, as the stipulations of the car concern are too restrictive. On the other hand, the MI value of, for example, power generation, can be directly influenced by one's own, if only partial, generation of power (cogeneration/trigeneration, solar energy). In addition, processes can be divided into points for optimisation according to type; following some examples.

Examples for the reduction of Material Input (MI):
- Choice of working materials (e.g. use of recyclable materials).
- Choice of production methods (e.g. use of energy efficient machines, water cycles).
- Special surface technology for reducing and preventing corrosion, friction, soiling (e.g. use of the "Lotus effect" to reduce the soiling of surfaces).
- Design (e.g. exchangeable kitchen fronts to suit fashion trends and resource-conserving use).
- Transport (e.g. simple robust transport possibilities, short distances).
- Packaging (e.g. multi-use systems).

- Material recycling, disposal (e.g. detachable connections, recyclability, minimal variety of materials).

Examples for the enhancement of the Service unit (S):
- Application, use (e.g. eco-wash programmes for washing machines, switching-off options for freezers, multi-purpose tools and equipment, long lifespan).
- Service, maintenance (e.g. exchange options for parts that are subject to wear and tear, up-grading possibilities).
- Re-usability (re-use of trade fair stands, a mustard jar becomes a drinking glass).
- Services with optimised resource input (e.g. renting of tools or machines which are seldom used).

Of course, a list like this only provides a selection of several typical possibilities. It does not automatically cover all areas of action, as the specific content is generally too complex.

Implementation in the enterprise:
If the MIPS concept is to be completely integrated into one's own enterprise as an ecological method of assessment, then it is recommended to start with a pilot project if this has not already occurred. During such a project where time and scope are restricted, the staff accustoms itself to the MIPS concept by using one or more objects of reference. The following procedure has proved worthwhile:

- ► Meetings of the employees concerned (design, planning, production, buying and selling department, etc.), of the decision-makers in management, maybe also of the suppliers, customers and target groups.
- ► Brainstorming: gathering of ideas (e.g. by means of mind mapping).
- ► Formulation of the most promising ideas (e.g. by means of a subjective point system by the participants).
- ► Assessment of the ideas according to certain criteria (e.g. operational know-how, the competition situation, value added).
- ► Detailed comparison of the "best" ideas in order of importance.
- ► Selection of the "best" ideas, planning and the implementation of the necessary measures.

Only after the satisfactory completion of a pilot project are the contents and methods of the MIPS concept introduced, step-by-step, into the individual departments and business processes.

A detailed description of all aspects connected with the application and implementation would go beyond the scope of this publication. If requested, the authors are ready to name qualified contact persons for the implementation of the MIPS concept in your enterprise or organisation.

Further information at www.mips-online.info

Glossary

Abiotic raw materials are all abiotic materials taken directly from nature and unprocessed, e.g. ores in a mine, “unused extraction of raw materials”, excavation of earth and sediment, etc.

Air is accounted for in the MIPS concept as long as it is changed chemically or physically, (aggregate state).

Auxiliary materials are substances that are involved in a process, but only fulfil a subsidiary function.

Average products represent a complete class of products. Single specific products can differ distinctly in their properties from average products.

Basic, working and building materials are materials or substances that are added in a process, and have been manufactured in previous processes for that purpose (e.g. steel, PVC or glass).

Biotic materials are all biotic materials taken directly from nature before processing, (e.g. trees, fish, cotton).

By-products are commercial goods that are produced during a process, but for which the process is not mainly operated.

Calculation sheets help with the systematic and structured calculation of individual processes. They are available on the given homepage.

Cycles: A series of natural but also technical substance flows can occur in cycles. A typical example is the natural water cycle.

Data sheets help with the systematic and structured compiling of data for single processes. They can be found at the given homepage.

Earth movement encompasses all movements of earth in agriculture and silviculture, i.e. all ploughed land or erosion.

Ecological rucksack: can be calculated by subtracting the net weight of the product from the Material Input; Ecological rucksack = MI – net weight.

Ecosphere is the natural environment of human beings.

Emissions: Air pollution, noise, vibrations, light, heat, rays and other phenomena.

Energy carriers are thermal or nonthermal carriers of energy (e.g. petroleum, oil, coal or firewood).

Exhaust air or waste gases are carrier gases of solid, liquid or gas emissions.

Calorific value (gross): The gross calorific value H_0 (former upper heating value) determines the relation of the released amount of heat from complete combustion to the mass of the combusted material. The gross calorific value does not consider that the usable amount of heat — as a rule — is reduced by the amount consumed by vaporisation of available or emerging water.

Calorific value (net): The net calorific value Hu (former lower heating value) determines the relation of the released amount of heat from complete combustion to the mass of the combusted material. The net calorific value does consider that the usable amount of heat —as a rule — is reduced by the amount consumed by vaporisation of available or emerging water. Therefore the net calorific value is smaller than the gross calorific value. In engineering the net calorific value is almost exclusively used.

General data refer to product classes, to typical or average products.

Infrastructure: all production means and machinery that are necessary for the production of goods are summarised here as infrastructure.

Input encompasses everything that goes into a process

Intermediary products are products that are manufactured in the process chain that do not yet perform a service or are not yet of use (a car battery in the case of a car).

Life-cycle-wide: encompasses all life phases, i.e. from the extraction of raw materials, through production, use and application, to the recycling and disposal of a product.

Main products are commercial products that are produced in a process, and for which the process is mainly operated.

Glossary

Material/substance flows are all flows of substances in the eco- and technosphere. Substance flows can move in cycles. Historical and also geological periods of time are too short to enable a life cycle for a series of material flows.

Material Input (MI) encompasses all material inputs, which are necessary for the manufacture of goods or for the provision of a service: Unit [kg or t].

Material Intensity (MIT) is the Material Input in relation to a unit of measurement; Unit [kg/kg or kg/MJ, etc.]. (Material Intensity = Material Input / Weight.)

Maximum estimations are carried out by recording the maximum possible material inputs. They are carried out when complete calculations are not possible, and when the maximum resource expenditure is wanted as a basis for comparison.

MI factors are the material intensity values for the single/individual materials or modules. Unit [kg/kg or kg/MJ, etc.].

Minimum estimations are carried out by recording the minimum possible input. They are carried out when complete calculations are not possible, and when the minimum resource expenditure is wanted as a basis for comparison.

MIPS is the abbreviation for Material Input Per Service unit. [Unit kg/S]; MIPS = MI/S

Modules contain data about the pre-products or the pre-services, which are needed and used frequently. They concern average values. Modules are relevant for individual regions, branches, etc. (transport module, electricity module, etc.).

Natural deposit of resources is where the resources can be found and where they are taken from for further processing (e.g. coal seam).

Operating materials are materials which are necessary for the functioning of a process, but which do not go into the product (e.g. cleaning agents and cloths).

Output: encompasses everything that comes out of a process

Passenger kilometres: the number of passengers transported multiplied by the number of kilometres covered equals the number of Passenger kilometres. [Pkm].

Pre-process-chains: Process chains of a pre-product.

Pre-product: Products, which are the input of another process.

Process is the procedure (machine, method, use) during which the inputs are converted into outputs by means of an action, whereby at least one intended output is produced (e.g. shaped metal sheet, a chemical or the transport of goods).

Process chain is the representation of the process system with the individual processes and their links.

Process picture is the schematic representation of the inputs and outputs of a single process.

Product classification: Comparisons can be carried out not only with actual products but also with product grades, e.g. white cotton T-shirt.

Production intensive are products whose manufacture causes greater resource expenditure than their use.

Production buildings are buildings in which manufacture takes place. They can be attributed to the processes through the life span of the buildings.

Production technologies are machinery, plants and tools, etc., which are necessary for the execution of a process, but are not used up in the process.

Resources are all ingredients for a process. The term “resource” in the MIPS concept is not used analogous to the geological or economic term.

Scope of data (scope of validity of data) indicates within which framework and under what conditions the data can be used and applied.

Specific data refers to a specific product or to a specific service (a pullover, size X, colour Y, producer Z).

Technosphere: the part of the ecosphere, which is directly affected by mankind.

Tonkilometre: the quantity of transported goods multiplied by the number of kilometres equals the number of tonkilometres.

Glossary

Use-intensive are products where use causes greater resource consumption than the manufacture.

Waste is substances or products, which can either be recycled or need to be disposed of.

Waste water is all water that is soiled, dirtied or polluted by domestic, agricultural, commercial and industrial use; (furthermore, rain water as well as water seeping through the ground from drainage and seepage pipes) that arrives in the draining ditch via the drainage system.

Water according to the MIPS concept encompasses all water taken from nature. A difference should be made between the extraction of surface water, ground water and deep ground (subterranean) water. On the basis of official water statistics, it is possible and also simpler to differentiate between: ground, surface and source water. Depending on the water statistics, enriched surface water and bank filtrate are also surveyed.

Appendix

Tables

Conversions

Energy	kJ	kcal	kWh	kg SKE	kg ROE
1 kilojoule (kJ)	–	0.2388	0.000278	0.000034	0.000024
1 kilocalorie (kcal)	4.1868	–	0.001163	0.000143	0.0001
1 kilowatt-hour (kWh)	3,600	860	–	0.123	0.086
1 kg mineral coal unit (SKE)	29,308	7,000	8.14	–	0.7
1 kg crude oil unit (RÖE)	41,868	10,000	11.63	1.428	–

Weights	kg	US short ton	Brit long ton	oz	lb.
1 kg	–	0.0011023	0.0009843	35.27337	2.295737
1 US short ton	907.185	–	0.892857	32,000	2,000
1 Brit long ton	1,016	1.12	–	35,840	2240
1 ounce (oz)	0.02835	0.00003125	0.0000279	–	0.0625
1 pound (lb.)	0.45359	0.0005	0.0004464	16	–

Lengths	m	in	ft	yd	mile(m)	nautic mile
1 meter (m)	–	39.37	3.2808	1.0936	0.0006215	0.000054
1 inch (in)/ Zoll	0.0254	–	$^{1}/_{12}$	$^{1}/_{36}$	$^{1}/_{63,360}$	$^{1}/_{72,960}$
1 foot (ft)	0.3048	12	–	$^{1}/_{3}$	$^{1}/_{5,280}$	$^{1}/_{6,080}$
1 yard (yd)	0.9144	36	3	–	$^{1}/_{1,760}$	0.0004934
1 mile (m)	1,609	63,360	5,280	1,760	–	0.86842
1 nautic mile	1,852	72,960	6,080	2,026 $^{2}/_{3}$	1.1515	–

Prefixes

Units often have prefixes, as they are sometimes too big or too small for usage. Only one prefix may be used at a time.

Prefix	Prefix character	Significance	Comment	Prefix	Prefix character	Significance	Comment
Atto	a	10^{-18}		Deka	da	10^{1}	unfavourable
Femto	f	10^{-15}		Hekto	h	10^{2}	unfavourable
Piko	p	10^{-12}		Kilo	k	10^{3}	
Nano	n	10^{-9}		Mega	M	10^{6}	
Mikro	µ	10^{-6}		Giga	G	10^{9}	
Milli	m	10^{-3}		Tera	T	10^{12}	
Zenti	c	10^{-2}	unfavourable	Peta	P	10^{15}	
Dezi	d	10^{-1}	unfavourable	Exa	E	10^{18}	

Density of substances

	kg/dm³ at 20 °C		kg/dm³ at 20 °C		kg/dm³ at20 °C
Aluminium	2.7	Titanium	4.52	Fuel oil El	0.85
Lead	11.34	Tungsten	19.3	Fuel oil S	>1.2
Steel	7.8	Gold	19.29	Diesel	0.85
Magnesium	1.74	Cast iron	7.2	Petrol	0.72
Brass	8.5	Iridium	22.4	Natural gas	0.78 kg/m³
Platinum	21.5	Copper	8.92		
Red brass	8.8	Zinc	7.14		
Mercury	13.55	Hardcoal	1.4		

Heating values of energy carriers

(source: Arbeitsgemeinschaft Energiebilanzen)

Energy carrier	unit-	Heating value [kJ]	Energy carrier	unit	Heating value [kJ]
Hard coal	kg	29,715	Diesel fuel	kg	42,960
Hard coal coke	kg	28,650	Fuel oil, light	kg	42,733
Hard coal briquettes	kg	31,401	Fuel oil, heavy	kg	40,852
Lignite	kg	8,575	Petroleum coke	kg	30,895
Lignite briquettes	kg	19,500	Liquid gas	kg	46,041
Lignite coke	kg	29,900	Refinery gas	kg	45,159
Pulverised and dry coal	kg	21,525	Coking plant gas City gas	cbm	15,994
Woody lignite	kg	16,747	Blast furnace gas	cbm	4,187
Firewood (1 cbm = 0,7 t)	kg	14,654	Natural gas	cbm	31,736
Fire peat	kg	14,235	Petroleum gas	cbm	40,300
Mineral oil (raw)	kg	42,633	Pit gas	cbm	15,994
Motor petrol, -benzol	kg	43,543	Sewer gas	cbm	15,994
Raw petrol	kg	44,000	Raw benzol	kg	39,565
Aviation petrol, light aviation turbine fuel	kg	43,543	Raw tar	kg	37,681
Heavy aviation turbine fuel, paraffin	kg	43,000	Pitch	kg	37,681

Calculation Examples

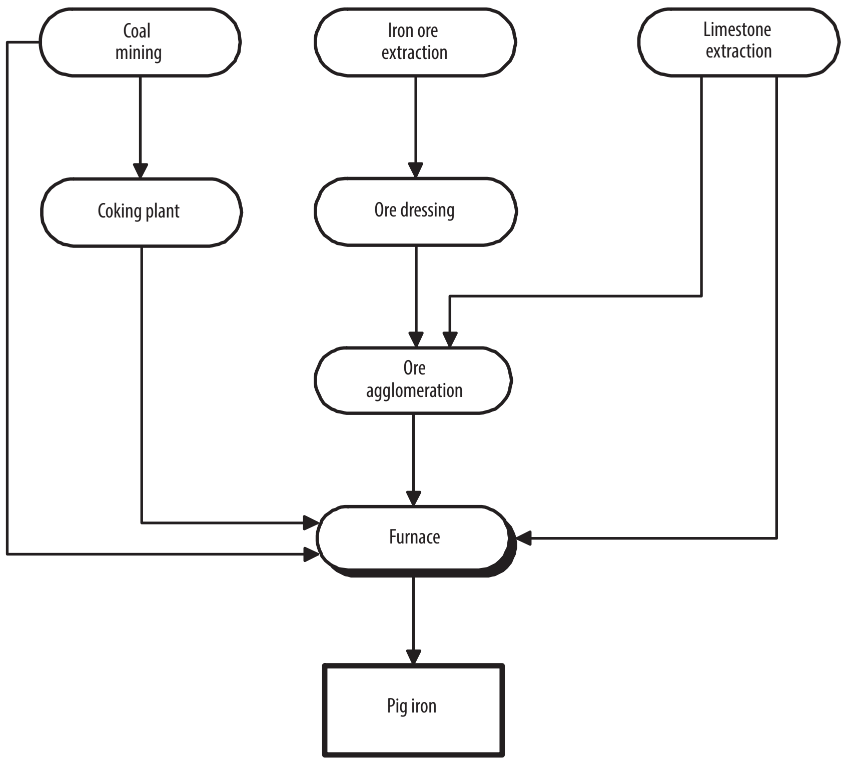
Example: Pig iron production

To illustrate the generation of MI data on the levels of basic, building and work materials, the pig iron production chain is shown and described below:

Step 1: Definition of the aim, the objects and of the Service unit
The aim of the analysis at this point is the calculation of the MI value of pig iron. No "real" Service unit can be used at this point in a comparison. However, in later comparisons, MI values drawn from weight units are easily applied (e.g. for the manufacture of steel elements). The given figures and data refer to the following sources: MIPS-online data sheet; WI-Paper No. 27: Wuppertal 1995, MI analysis of basic, building and work materials.

STEP 2: The representation of a process chain
The process chain for the production of pig iron can be taken from the following illustration.

Pig iron production chain



STEP 3: Compiling of data

The collection of data encompasses

- the gathering of data about ore-deposits,
- the gathering of data about coal and limestone deposits,
- the gathering of data about coking plants, of sinter and pellet plants, about energy plants and
- the compiling of data about blast furnaces.

STEPS 4 and 5: Calculation of the material input "from the cradle to the substance"

The following intermediary steps must be taken to calculate a MI value for pig iron by means of the compiled data. The calculation of MI values for the main products of the relevant processes:

- Hard coal from coal mining,
- Iron ore and pellets from open cast mining,
- Limestone from quarries,
- Coke from the coking plant,
- Sinter from the sintering plant,
- Pellets from the pellet plant.

In addition, MI values need to be determined or find out for transport, electric power and different fuels.

The calculation of the single processes is illustrated in the following calculation sheets. The necessary material intensities of individual substances are listed in the following table:

Substance	Abiotic material	Water	Air
Hard coal	2.36 kg/kg	9.1 kg/kg	0.048 kg/kg
Electric power, steel industry	4.22 kg/kWh	72.5 kg/kWh	0.607 kg/kWh
Electric power, OECD countries	1.55 kg/kWh	66.7 kg/kWh	0.535 kg/kWh
Diesel	0.032 kg/MJ	0.23 kg/MJ	0.076 kg/MJ
Limestone	1.66 kg/kg	9.7 kg/kg	0.06 kg/kg
Natural Gas	0.03 kg/MJ	0.012 kg/MJ	0.09 kg/MJ

Calculation sheet
Data refer to: 1 ton extracted iron ore (Fe-content: 46%)

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Iron ore and overburden	kg	1,882.00	1.000	1,882.00								
Diesel	MJ	58.00	0.032	1.86					0.23	13.34	0.08	4.41
Explosives	kg	0.27	1.000	0.27								
Electricity	kWh	1.42	1.550	2.20					66.70	94.71	0.54	0.76
∑				1,886.33		0.00		0.00		108.05		5.17

Calculation sheet
Data refer to: 1 ton dressed iron ore (Fe-content: 65%)

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Iron ore (46% Fe)	kg	1,658.00	1.886	3,126.99					0.11	179.06	0.01	8.29
Electricity	kWh	18.71	1.550	29.00					66.70	1,247.96	0.54	10.01
Water	kg	1,519							1.00	1,519.00		
∑				3,155.99		0.00		0.00		2946.02		18.30

Calculation sheet
Data refer to: 1 ton agglomerated iron ore (sinter and pellets)

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Iron ore (65% Fe)	kg	1,033.00	3.156	3,260.15					2.95	3,043.22	0.02	18.59
Limestone	kg	46.50	1.660	77.19					9.70	451.05	0.06	2.79
Natural gas	MJ	228.00	0.030	6.84					0.01	2.74	0.09	20.52
Compressed air	Nm3	2.20									1.29	2.84
Electricity	kWh	41.10	1.550	63.71					66.70	2,741.37	0.54	21.99
Water	kg	379							1.00	379.00		
∑				3,407.88		0.00		0.00		6,617.37		66.73

Calculation sheet
Data refer to: 1 ton coke

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Mineral coal	kg	1,350.00	2.360	3,186.00					9.10	12,285.00	0.05	64.80
Fuel, secondary	MJ	3,500.00	0.000	0.00					0.00	0.00	0.00	0.00
Water	kg	50.00	1.000	50.00					1.00	50.00		
Electricity	kWh	33.06	4.220	139.51					72.50	2,396.85	0.61	20.07
Air	kg	1,600									1.00	1,600.00
∑				3,375.51		0.00		0.00		14,731.85		1,684.87

Calculation sheet
Data refer to: 1 ton pig iron

			Abiotic Material		Biotic Material		Earth movements		Water		Air	
Name Substance/pre-product	Unit	Amount	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product	MI-Factor kg/unit	kg/unit Main product
Sinter	kg	1,034	3.41	3,522.84					6.62	6,841.98	1.03	1,067.09
Pellets	kg	404	3.41	1,376.43					6.62	2,673.27	1.03	416.12
Coke	kg	475	3.38	1,603.13					14.73	6,996.75	1.69	800.38
Limestone	kg	13	1.66	21.91					9.70	128.04	0.06	0.79
Hardcoal	kg	57	2.36	135.23					9.10	521.43	0.05	2.75
Water	kg	12,032							1.00	12,032.00		
Electricity	kWh	92	4.22	388.24					72.50	6,670.00	0.61	55.84
$\sum$				7,047.77		0.00		0.00		35,863.47		2,342.97

The last calculation sheet for raw iron shows the calculated value of the complete process:

- 7.05 tons of abiotic material,
- 35.9 tons of water and
- 2.34 tons of air

were used to produce 1 ton of raw iron!

STEP 6: From Material Input to MIPS

This step does not need to be carried out because of the selected objective (calculation of a MI value for a basic material, and not for the MIPS of a product (See note on page 16).

STEP 7: Interpretation of the results

In the case of the selected objective, an interpretation of the results can only occur on the basis of the Material Input within a single process. An underlying discussion about a change in the pig iron production process, based on such data, is pointless outside of the steel industry. In addition, the process has been adequately optimised technically. Optimising possibilities can be determined on the level of choice of power generation or of specific deposits, albeit only to a very limited extent when compared to serviceable products (e.g. halls or vehicles made of steel).

Example: Carpet cleaner

To illustrate the application of the MIPS manual, a MIPS calculation will be demonstrated in the following example of two alternative carpet cleaners.

STEP 1: Definition of the aim, the objects and of the Service unit
The aim of the MIPS calculation here is the comparison of two (different) carpet cleaning alternatives, whereby the objects under scrutiny have already been selected. The chosen Service units are:

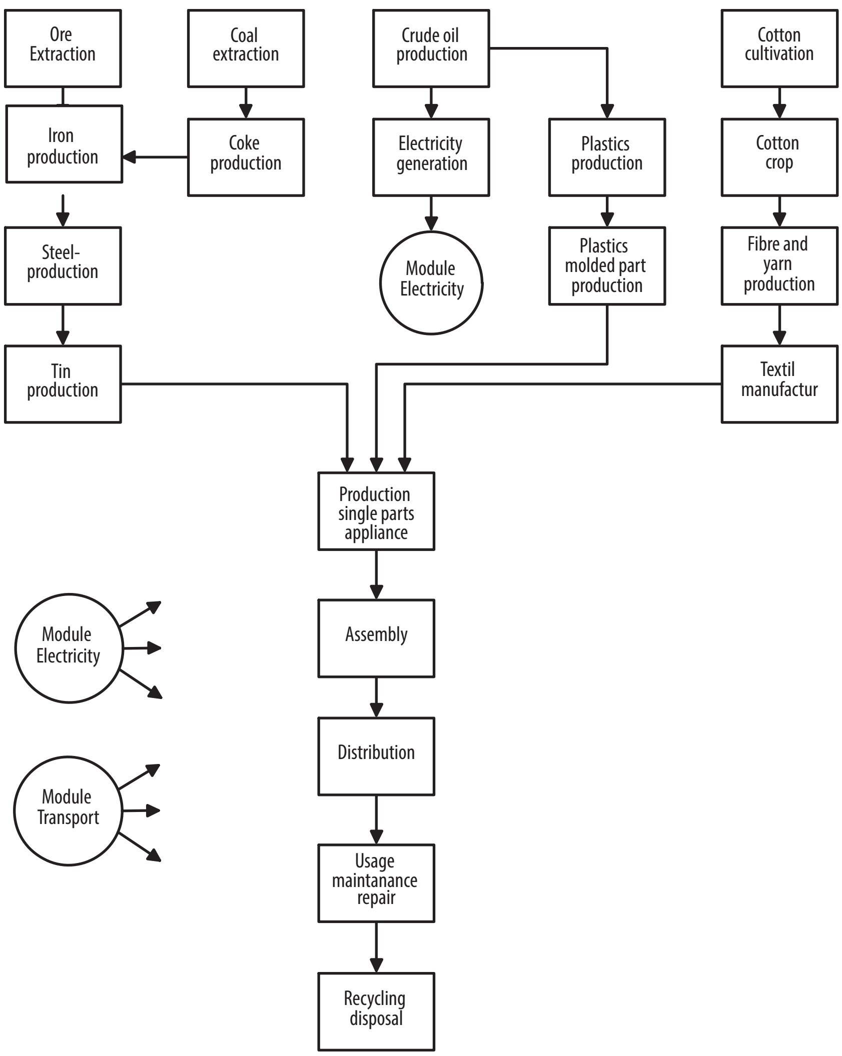
- one hour of carpet cleaning,
- one year of carpet cleaning (assuming X hours per week),
- carpet cleaning throughout the whole life span of the product.

The choice of three different Service units enables a detailed comparison of both alternatives.

STEP 2: Representation of the process chain

The process chain of the manufacture, the use and disposal of the carpet cleaners is extensive, and includes the pre-processes of the production of the materials, energy carriers, electrical power, etc. No data is available on the actual manufacturing of the appliance, i.e. neither on the manufacture nor on the assembly of the individual components. For example, it is not known how much waste occurs during production, i.e. unused building materials, or how much electricity is used by the machines. This example is not unusual as there are often gaps like this in the available information.

Even so, in order to be able to calculate the MIPS value, a simplification is carried out as is often the case. The MI value of the product is worked out using only the actually existing substances in the product. The weight amounts are multiplied by the available and suitable Material Intensity values, the so-called MI factors. In this way, a pretty solid MI value can be arrived at in a relatively simple and swift manner. This MI value becomes the required MIPS, and thus a measurement of comparison, by referring to the specific Service unit.



STEP 3: The compiling of data

This step encompasses the following:

- The weight analysis of the product,
- The estimation of the phases of use, disposal and/or recycling,
- The compiling of the appropriate MI factors.

Weight share of products

Material	kg per appliance
Material compound of carpet sweeper	
Steel (primary)	3.15
Plastics	0.04
Renewable raw materials	0.08
Total	**3.27**
Material compound of carpet cleaner	
Steel (primary)	1.85
Plastics	2.1
Aluminium (primary)	0.247
Copper (50% prim. /50% sec.)	0.12
Tin	0.001
Oil	0.002
Cotton	0.1
Total	**4.42**

Usage and disposal/recycle phase

Carpet sweeper (Life span: 30 years)	Carpet cleaner (Life span: 10 years)
Expenditures during the use-phase	
1 brush from renewable resources (0.08 kg)	12 dust bags (0.1 kg per piece)
0.1 kg cleaning agent	108 kWh electricity consumption
50 km to recycling station (collective lorry)	50 km to recycling station (collective lorry)

Number of dust bags and energy consumption were estimated:

- dust bags: 1 bag per month
- energy consumption: 1,500 Watt power; 1.5 h vacuuming/week; 48 weeks/year

Information on Material Intensities (MI factors)

Material	Material abiotic t/t	Material biotic t/t	Earth movements t/t	Water t/t	Air t/t
Material Intensities of materials, energy carriers and transport (these values can change over the years; valid data at: www.mips-online.info)					
Steel, primary	6.97			44.6	1.3
Steel, secundary	3.36			57.5	0.56
Aluminium, primary	85.38			1378.6	9.78
Aluminium, secundary	3.45			60.9	0.37
Copper, primary	500.0			260.0	2.0
Copper, secundary	9.66			105.6	0.72
Plastics (PVC)	8.02			117.7	0.69
Plastics (PE)	5.4			64.9	2.1
Tin (estimated)	6800.0			no information	no information
Oil (here heating oil)	1.5			11.4	0.03
Renewables: here as approximate:					
Cotton (here USA, west)	8.6	2.9	5.01	6814.0	2.74
Paper (primary)	1.2	5.0		14.7	0.24
Cleaning agent	6.0			98.0	0.7
	t/MWh	t/MWh		t/MWh	t/MWh
Electric Power (Germany, public supply)	4.7			83.1	0.6
	kg/tkm	kg/tkm		kg/tkm	kg/tkm
Road goods transport without infrastructure (here: truck-trailer > 8t)	0.107			0.927	0.1
Infrastructure (here: all roads)	0.749			5.16	0.017

Data sheet:
Data refer to: 1 kg top (carded and combed sliver)

Name			Abiotic material		Biotic material		Earth movements		Water		Air	
Material/pre-product	Unit	Amount	MI-factor kg/unit	kg/unit main product	MI-factor kg/unit	kg/unit main product	MI-factor kg/unit	kg/unit main product	MI-factor kg/unit	kg/unit main product	MI-factor kg/unit	kg/unit main product
Raw wool	kg	1.670	3.11	5.19	103.00	172.01			1.42	2.37	0.04	0.06
Synthetic detergent	kg	0.014	1.00	0.01					no info		no info	
Liquefied material	kg	0.004	1.00	0.00					no info		no info	
Soda	kg	0.009	4.46	0.04					27.72	0.25	1.02	0.01
Polyethylene	kg	0.011	5.40	0.06					64.90	0.71	2.10	0.02
Electricity	kWh	3.460	4.70	16.26					83.06	287.39	0.60	2.08
Water	kg	15.530	0.00						1.00	15.53		
∑				21.57		172.01		0.00		306.25		2.17

STEPS 4 and 5: The calculation of the Material Input "from cradle to product" and "from cradle to grave"

Steps 4 and 5 are combined on the calculation sheet.

STEP 6: From Material Input to MIPS

The MI values added up for each piece of equipment, in relation to the whole life span, now refer to the three Service units selected at the beginning:

- an hour of carpet cleaning,
- a year of carpet cleaning,
- carpet cleaning during the whole life span of the product.

In addition, the MI values, which were previously calculated for the whole life span (10 or 30 years), are calculated for one hour or for one year accordingly.

MIPS — given in TMR

Service unit	Carpet sweeper (Life span: 30 years)	Carpet cleaner (Life span: 10 years)
Total life span	78.71 kg	5,174 kg
One year carpet cleaning	2.6 kg	517 kg
One time carpet cleaning	0.02 kg	3.6 kg

STEP 7: Interpretation of the results

The listed values alone clearly demonstrate the difference in the use of materials, TMR, of both carpet cleaners. In addition, if the life-cycle phases are looked at separately (see fig ox), then it can be seen that the phase of use of the conventional vacuum cleaner is the decisive factor, in particular regarding the use of resources due to electricity consumption.

MIPS (given in TMR) per life-cycle phase

Life-cycle phase	Carpet sweeper (Life span: 30 years)	Carpet cleaner (Life span: 10 years)
Manufacture	23.5 kg	84.4 kg
Usage	55 kg	5,150 kg
Disposal/Recycling	0.24 kg	0.2 kg

In this case, a subsequent optimisation of the product based on this calculation is also possible: optimising the conventional carpet cleaner during the phase of use where the most raw materials are used. An optimisation beyond the already existing product provided the designer, Agim Meta, the opportunity to create a comparable “carpet sweeper”. Starting with the conventional carpet cleaner, a carpet cleaner has been conceived and designed which uses the least possible resources. And we are of the opinion that the comparison is well worth looking into!

Worth-knowing

Literature

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Schmidt-Bleek, F.; Bringezu, S.; Hinterberger, F.; Liedtke, C.; Spangenberg, J.; Stiller, H.; Welfens, M. J.: Handbuch der Materialintensitätsanalyse MAIA.: Berlin; Basel; Boston: Birkhäuser Verlag, 1998

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Further information and links

www.mips-online.info

www.wupperinst.org

www.factor10.de

Software/Eco-auditing programmes

Gabi® vom Institut für Kunststoffprüfung und Kunststoffkunde (IKP), Uni Stuttgart und PE Product Engineering GmbH: www.ifeu.de bzw. www.ifu.com

Umberto® des Ifeu (Institut für Energie- und Umweltforschung, Heidelberg) und Ifu (Institut für Umweltinformatik, Hamburg): www.gabi-software.com

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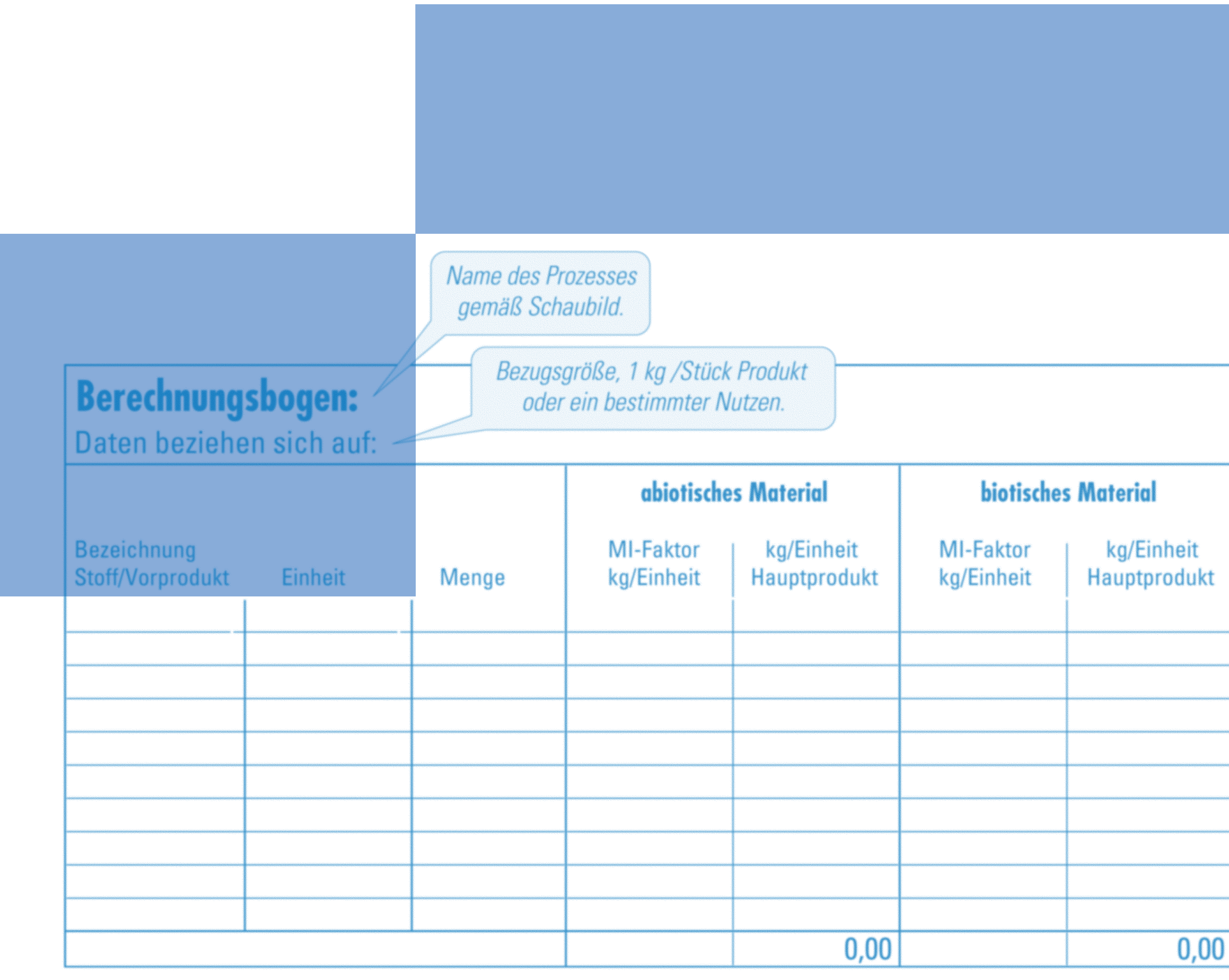
Name des Prozesses gemäß Schaubild.

Bezugsgröße, 1 kg /Stück Produkt oder ein bestimmter Nutzen.

Berechnungsbogen:
Daten beziehen sich auf:

Bezeichnung Stoff/Vorprodukt	Einheit	Menge	abiotisches Material MI-Faktor kg/Einheit	abiotisches Material kg/Einheit Hauptprodukt	biotisches Material MI-Faktor kg/Einheit	biotisches Material kg/Einheit Hauptprodukt
				0,00		0,00