TECHNICAL REPORT

**ISO/TR 14049**

First edition
2000-03-15

# Environmental management — Life cycle assessment — Examples of application of ISO 14041 to goal and scope definition and inventory analysis

*Management environnemental — Analyse du cycle de vie — Exemples d'application de l'ISO 14041 traitant de la définition de l'objectif et du champ d'étude et analyse de l'inventaire*



Reference number
ISO/TR 14049:2000(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 734 10 79
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

## Contents

Page

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

ISO/TR 14049 was prepared by Technical Committee ISO/TC 207, *Environmental management*, Subcommittee SC 5, *Life cycle assessment*.



## Introduction

The heightened awareness of the importance of environmental protection, and the possible impacts associated with products manufactured and consumed, has increased the interest in the development of methods to better comprehend and reduce these impacts. One of the techniques being developed for this purpose is Life Cycle Assessment (LCA). To facilitate a harmonized approach, a family of standards on life cycle assessment (LCA), including ISO 14040, ISO 14041, ISO 14042 and ISO 14043 and this document are being developed by ISO. These International Standards describe principles of conducting and reporting LCA studies with certain minimal requirements.

This Technical Report provides supplemental information to the International Standard, ISO 14041, *Environmental management - Life cycle assessment - Goal and scope definition and life cycle inventory analysis*, based on several examples on key areas of the Standard in order to enhance the understanding of the requirements of the standard.

Methodological requirements for conducting LCA studies are provided in the following International Standards concerning the various phases of LCA:

— ISO 14040: *Environmental management - Life cycle assessment - Principles and framework.*

— ISO 14041: *Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis.*



— ISO 14042: *Environmental management - Life cycle assessment - Life cycle impact assessment*.



— ISO 14043: *Environmental management - Life cycle assessment - Life cycle interpretation*.

# Environmental management — Life cycle assessment — Examples of application of ISO 14041 to goal and scope definition and inventory analysis

## 1 Scope

This Technical Report provides examples about practices in carrying out an Life Cycle Inventory analysis (LCI) as a means of satisfying certain provisions of ISO 14041. These examples are only a sample of the possible cases satisfying the provisions of the standard. They should be read as offering “a way” or “ways” rather than the “unique way” of applying the standard. Also they reflect only certain portions of an LCI study.

It should be noted that the examples presented in this Technical Report are not exclusive and that many other examples exist to illustrate the methodological issues described. The examples are only portions of a complete LCI study.

## 2 Technical Introduction



The examples focus on six key areas of ISO 14041 as indicated in Table 1.



In some key areas there is more than one example. The reason is that in many cases more than one practice exists. The decision about the application of one or the other practices is goal dependent and can vary e.g. from the product system under investigation or in the stages over the life cycle. The examples are described in the context of the corresponding provisions of the standard and with the specific use.

In the description of the different cases, whenever possible, the following structure has been adopted :

– Context of the standard

– Overview

– Description of the examples

**Table 1 – Cross references between ISO 14041 and examples in this document**

| ISO 14041 | Examples in ISO/TR 14049 |
|---|---|
| 0 Introduction | |
| 1 Scope | |
| 2 Normative reference | |
| 3 Terms and definitions | |
| 4 LCI components | |
| 4.1 General | |
| 4.2 Product system | |
| 4.3 Unit process | |
| 4.4 Data categories | |
| 4.5 Modelling product systems | |
| 5 Definition of goal and scope | |
| 5.1 General | |
| 5.2 Goal of the study | |
| 5.3 Scope of the study | |
| 5.3.1 General | |
| 5.3.2 Function, functional unit and reference flow | 3 Examples of developing functions, functional units and reference flows<br>4 Examples of distinguishing functions of comparative systems |
| 5.3.3 Initial system boundaries | |
| 5.3.4 description of data categories | |
| 5.3.5 Criteria for initial inclusion of inputs and outputs | 5 Examples of establishing the inputs, outputs and boundary of unit process<br>10 Examples of performing sensitivity analysis |
| 5.3.6 Data quality requirements | 9 Examples of conducting data quality assessment |
| 5.3.7 Critical review | |
| 6 Inventory analysis | |
| 6.1 General | |
| 6.2 Preparing for data collection | |
| 6.3 Data collection | 9 Examples of conducting data quality assessment |
| 6.4 Calculation procedures | |
| 6.4.1 General | |
| 6.4.2 Validation of data | 9 Examples of conducting data quality assessment |
| 6.4.3 Relating data to the unit process | |
| 6.4.4 Relating data to functional unit and data aggregation | 3 Examples of developing functions, functional units and reference flows |
| 6.4.5 Refining the system boundaries | 10 Examples of performing sensitivity analysis |
| 6.5 Allocation of flows and releases | |
| 6.5.1 General | |
| 6.5.2 Allocation principles | 6 Examples of avoiding allocation |
| 6.5.3 Allocation procedure | 6 Examples of avoiding allocation<br>7 Examples of applying allocation |
| 6.5.4 Allocation procedures for reuse and recycling | 8 Examples of applying allocation procedures for recycling |
| 7 Limitation of LCI (interpreting LCI results) | 9 Examples of conducting data quality assessment<br>10 Examples of performing sensitivity analysis |
| 8 Study report | |
| ANNEX | |
| A Example of a data collection sheet | |
| B Examples of different allocation procedures | |

# 3 Examples of developing functions, functional units and reference flows

## 3.1 Context of the standard

ISO 14041 states in 5.3.2 that:

— In defining the scope of an LCA study, a clear statement on the specification of the functions (performance characteristics) of the product shall be made.

— The functional unit defines the quantification of these identified functions. The functional unit shall be consistent with the goal and scope of the study.

— One of the primary purposes of a functional unit is to provide a reference to which the input and output data are normalized (in a mathematical sense). Therefore the functional unit shall be clearly defined and measurable.

— Having defined the functional unit, the amount of product which is necessary to fulfil the function shall be quantified. The result of this quantification is the reference flow.

and in 6.4.4 that:

— Based on the flow chart and systems boundaries, unit processes are interconnected to allow calculations on the complete system. This is accomplished by normalizing the flows of all unit processes in the system to the functional unit. The calculation should result in all system input and output data being referenced to the functional unit.



## 3.2 Overview

In defining a functional unit and determining the reference flows, the following steps can be distinguished:

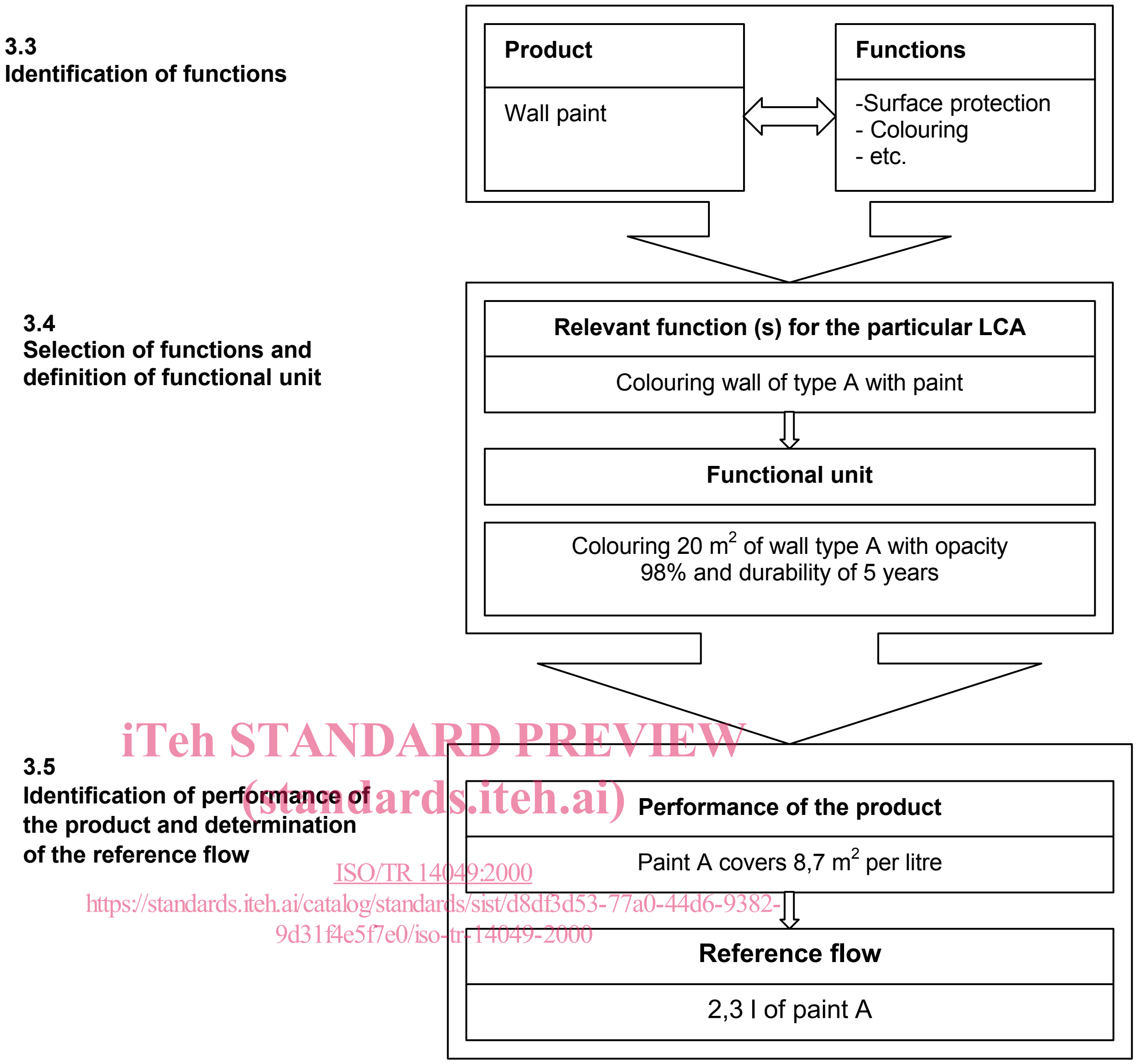


— identification of functions;

— selection of functions and definition of functional unit;

— identification of performance of the product and determination of the reference flow.

The sequence of these steps is depicted in Figure 1 using the example of paint. This example is also used in the following text (3.3 to 3.5). Further examples are given in 3.6.






Note: It is possible to start with either the product or with the function itself.

**Figure 1 – Overview of the example**

## 3.3 Identification of functions

The purpose of the functional unit is to quantify the service delivered by the product system. The first step is thus to identify the purpose served by the product system, i.e. its function or functions.

The starting point for this procedure may be a specific product to be studied (e.g. wall paint) or it may be the final need or goal, which in some cases may be fulfilled by several distinct products (e.g. wall decoration, which may be fulfilled by both paint and wallpaper or a combination of these).

The functions are typically related to specific product or process properties, each of which may:

- fulfil specific needs and thereby have a use value, which typically creates economic value to the supplier of the product,
- affect the functioning of other economic systems (e.g. wallpaper may have a - small - insulation effect, thus affecting the heat requirement of the building).

## 3.4 Selection of functions and definition of functional unit

Not all functions may be relevant for a particular LCA. Thus, out of all the possible functions, the relevant ones must be identified.

For a solid interior wall, for example, surface protection may be unnecessary, while colouring is a relevant function of paint.

Subsequently, the relevant functions are quantified in the functional unit, which may be expressed as a combination of different parameters.

For wall colouring, the functional unit will typically have to specify the area to be covered (e.g. 20 $m^2$), the type of wall (especially regarding its absorption and binding properties), the ability of the paint to hide the underlying surface (e.g. 98 % opacity), and its useful life (e.g. 5 years).

In the case of multifunctional units, the different quantities are sometimes linked, e.g. a wall covering insulation material may be available with a pre-coloured surface, which makes colouring unnecessary, thus delivering both insulation and colouring. The functional unit could then be:

"20 $m^2$ wall covering with a heat resistance of 2 m·K/W, with a coloured surface of 98 % opacity, not requiring any other colouring for 5 years".

Other examples of multifunctional units are given in Table 2.

**Table 2 – Examples of functional units for systems with multiple functions.**



| **Example No.** | **(1)** | **(2)** |
|---|---|---|
| **System** | **Paper recycling** | **Cogeneration** |
| Functions | - Recovery of waste paper, and<br>- Production of de-inked pulp<br>- etc. | - Generation of electric power, and<br>- Production of steam<br>- etc. |
| Selected function for a particular LCA | - Recovery of waste paper, or<br>- Production of de-inked pulp | - Generation of electric power, or<br>- Production of steam |
| Functional unit | - Recovery of 1 000 kg waste paper, or<br>- Production of 1 000 kg pulp for newsprint | - Generation of 100 MW electricity, or<br>- Production of 300 000 kg steam per hour at 125 °C and 0,3 MPa (3 bar) |

## 3.5 Identification of performance of the product and determination of the reference flow

Having defined a certain functional unit, the next task is to determine the quantity of product which is necessary to fulfil the function quantified by the functional unit. This reference flow is related to the product's performance, and is typically determined as the result of a standardized measurement method. Of course, the nature of this measurement and calculation depends on the studied product.

For paint, the reference flow is typically expressed as the amount of litres necessary for covering the surface area as defined by the functional unit. For example, in a standardized test, paint A may be determined to cover 8,7 $m^2$ per litre (i.e. the performance of the product). Using the example illustrated in Figure 1, this requires 2,3 l to cover the 20 $m^2$ of the functional unit, provided that the conditions in the standardized test are similar to those required by the functional unit (with regard to surface type and opacity).

The functional unit may already be expressed in terms of quantities of products, so that the functional unit and the reference flow are identical. Table 2 gives examples of such functional units, which are already expressed in terms of quantities of products.

### 3.6 Additional examples

The following three examples further illustrate the procedure in developing functions, functional units, and reference flows.

**Table 3 – Further examples of developing functions, functional units, and reference flows**

| Example No. | (1) | (2) | (3) |
|---|---|---|---|
| Product | Light bulb | Bottle | Hand drying |
| Functions | - Providing illumination<br>- Generating heat<br>- etc. | - Protection of beverage<br>- Facilitating handling<br>- Part of product image<br>- etc. | - Drying hands<br>- Removing bacteria<br>- etc. |
| Selected function for a particular LCA | Providing illumination (outdoor lamp only) | Protection of beverage | Drying hands (hygienic function judged irrelevant) |
| Functional unit | 300 lx in 50 000 h matching the daylight spectrum at 5 600 K. | 50 000 l of beverage protected between tapping and consumption | 1 000 pairs of hands dried |
| Performance of the product | 100 lx with a lifetime of 10 000 h | 0,5 l one-way bottle | One paper towel for drying one hand |
| Reference flow | 15 daylight bulbs of 100 lx with a lifetime of 10 000 hours | 100 000 one-way bottles of volume 0,5 l | 2 000 paper towels |



## 4 Examples of distinguishing functions of comparative systems

### 4.1 Context of the standard

ISO 14041 states in 5.3.2 that:

— Comparisons between systems shall be made on the basis of the same function, quantified by the same functional unit in the form of their reference flows.

— If additional functions of any of the systems are not taken into account in the comparison of functional units, then these omissions shall be documented. For example, systems A and B perform functions *x* and *y* which are represented by the selected functional unit, but system A also performs function *z*, which is not represented in the functional unit. It shall then be documented that function *z* is excluded from its functional unit. As an alternative, systems associated with the delivery of function *z* may be added to the boundary of system B to make the systems more comparable. In these cases, the processes selected shall be documented and justified.

### 4.2 Overview

When comparing product systems, special attention has to be made to confirm that the comparison is based on the same functional unit and equivalent methodological considerations, such as performance, system boundaries, data quality, allocation procedures, decision rules on evaluating inputs and outputs. In this chapter, some possible approaches will be described and illustrated by examples.

The general steps to be taken in comparative studies are illustrated in Figure 2.

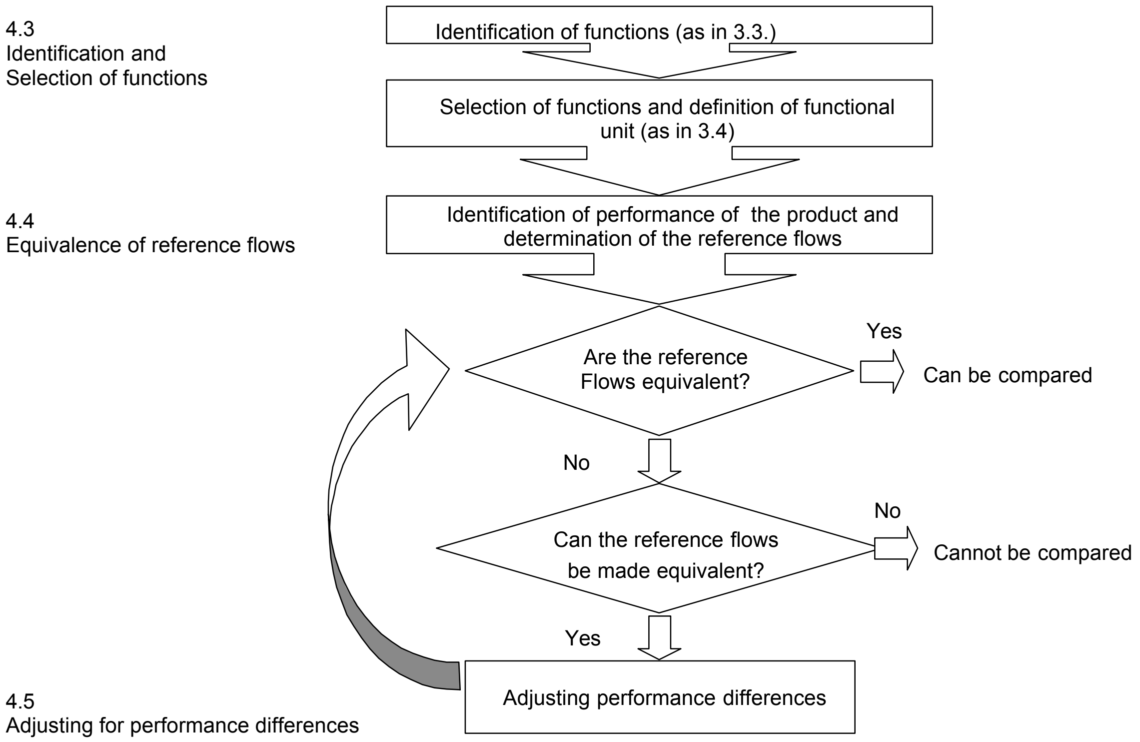





**Figure 2 – Overview of the steps in comparative studies**



## 4.3 Identification and selection of functions

The definition of the functional unit is closely bound to the goal of the study. If the goal is to compare product systems, special care will have to be paid in order to ensure that the comparison is valid, that any additional functions are identified and described, and that all relevant functions are taken into account.

Example 1: A study on waste management should include other functions than simply disposing of waste (i.e. the functions performed by the recycling systems in providing recycled material or energy).

Example 2: A study on electric household equipment should include the waste heat delivered to the building in which the equipment operates, as this influence the amount of heating and/or cooling required.

For comparative studies, the selection of functions becomes much more important than in non-comparative studies. Referring to the functions in Table 3:

— For bottles (example 2), leaving out of the image function of the packaging may lead to comparison of packagings that are technically similar (i.e. containing the same volume of beverage), but which the producer or customer will not accept as comparable.

— For hand-drying systems (example 3), leaving out the hygienic function may be regarded as unacceptable, e.g. in the food industry, where the bacteria-removing ability of paper towels may be regarded as such an advantage that a comparison to electrical hand-drying systems may not even be considered.

## 4.4 Equivalence of reference flows

The functional unit of the paint example from Clause 3 was "colouring 20 $m^2$ of wall type A with opacity 98 % and durability of 5 years". This functional unit can be supplied by several different reference functions:

2,3 l of paint A,

1,9 l of paint B,

1,7 l of paint C, etc.

These reference flows will have been calculated based on a test using standard conditions, concerning e.g. surface type and opacity.

The standardised test conditions and measurement methods must be appropriate to the intended comparison: In the hand drying example (example 3 in Table 3), it may be irrelevant to use a standardized test based on the technical properties of the paper such as mass, absorption-power and tensile strength, if the actual weight of paper used depends on the dispenser design. A more appropriate measure would then be data collected by weighing the paper stock at the start and the end of an adequate period in which the number of hands dried are determined by electronic surveillance of actual wash basins located in relevant institutions. Similarly, technical specifications of an electrical hand drier, such as the volume of air and its temperature, may be irrelevant as a basis for calculating the reference function, if the actual running time of the device is fixed by other factors, e.g. a built-in timer. Then, all that is needed is the running time and the electrical capacity of the equipment.

In the case of the light bulb (example 1 in Table 3), the functional unit of "300 lx in 50 000 h" may be provided by:

— 5 times 3 bulbs of 100 lx with a lifetime of 10 000 h each, or

— 10 times 2 bulbs of 150 lx with a lifetime of 5 000 h each.



The underlying premises of comparing 3 bulbs of 100 lx with 2 bulbs of 150 lx are:

— that the light spectrum of the two bulb types are comparable (or that the difference is acceptable to the user),



— that the 3 and 2 bulbs, respectively, can be placed so that the distribution of light is equal (or that the difference is acceptable to the user),

— that the sockets and other fixtures are not affected by the choice (in which case they would have to be included in the comparison).

Also, the two light bulbs were regarded as comparable in spite of their difference in lifetime. This difference is simply taken into account in the calculation of the reference flow. However, for long-lived products, such as refrigerators with lifetimes of 10 or 20 years, technology development may be a factor that cannot be disregarded. One refrigerator with a lifetime of 20 years cannot simply be compared to two successive, present-day refrigerators with a lifetime of 10 years. The refrigerators available 10 years from now are certain to be more energy efficient (i.e. lower energy input per functional unit) than the present, the energy efficiency of the second refrigerator of the 10 + 10 option must be determined by a trend projection, while the energy efficiency of the 20 years option is fixed.

The 100 000 one-way bottles of volume 0,5 l (example 2 in Table 3) may technically fulfil the same function of protecting 50 000 l of beverage, as would 12 500 returnable bottles of volume 0,4 l with a reuse rate of 90 %. However, in some situations the consumer may not always be able to distinguish between bottles of different volumes or masses. If the consumer regards 1 bottle equal to 1 bottle, the total consumption of beverage will decrease when the returnable bottles are introduced. In this case, the packaging cannot be studied independent of its contents. This is an example of the "No"-arrow leaving to the right in Figure 2. Of course, the goal of the study may then be redefined allowing for a comparison of beverage plus packaging taking into account the changes in consumption.

Another example of non-comparable functions (the "No"-arrow to the right in Figure 2), is that of two freezers, one with and one without quick-freeze option. If the quick-freeze option is regarded as an essential function by the consumer, the two freezers are simply not comparable and they cannot be made comparable by any calculation or system expansion. The same is true for the examples given at the end of 4.3.

In some systems with multiple functions, such as those in Table 2, the functions may be separated and delivered by several systems:

— Disposing the waste paper in an incineration plant and producing the pulp from virgin fibres may provide the same functional unit as the paper recycling system.

— Separate power and district heating units, respectively producing only electric power and only heat, may deliver the same functional unit as the co-generation plant.

However, some functions may be so intimately linked that separation is not possible. For example, the heat generation of a light bulb cannot be detached from its primary function.

In other situations, separations of two linked functions may be technically possible, but due to other aspects, the two separate functions may still not be regarded as comparable to the joint functions. An example of this is the combined freezer-refrigerator, which may or may not be compared to a freezer and separate refrigerator, depending on the acceptability of this choice to the consumer (the latter option will typically take up more space than a combined option with the same internal volumes).

Note that in most of the examples above, the equivalence of two products is determined by user acceptance. This acceptance, and thus whether two products are regarded as comparable or not, may be influenced by the price of the alternatives and by the additional information given along with the products, e.g. information on their environmental performance. Thus, for the purposes of product development or strategic management, it may be reasonable to compare two products which are not immediately regarded as equivalent, but where it is assumed that they will be regarded as equivalent under specific conditions of price and information.

## 4.5 Adjusting for performance differences



In those cases where the reference flows are immediately equivalent (as in the paint example at the top of 4.4) no adjustment is necessary.

In other cases, adjustment is necessary. The adjustment procedure follows the same principles as for co-product allocation, i.e. the preferred option is modification of the system boundaries to avoid the performance difference. In some cases, when this modification is not possible or feasible, allocation may be applied. In this section, examples are given of both options.

In the case of the light bulb in 4.4, it may be necessary to adjust the one of the systems to be compared (expanding it with an extra bulb socket). Another, more radical, example of such a system expansion or reconsideration of the studied functions, is that mentioned under the bottle example in 4.4, where the inclusion of the beverage was necessary.

A comparison of refrigerators may be based on their internal and/or external volume. The primary function is obviously related to their internal volume, but the external volume may a determining function, if the refrigerator is to be fitted into an existing kitchen. If the external volume is required to be equal, the internal volume may differ because of differences in insulation thickness. This can only be adjusted for by assuming differences in behaviour of the user (e.g. shopping more often, storing certain items outside the refrigerator, adding another secondary refrigerator elsewhere in the house). Each of these changes in behaviour will involve changes in different processes, which then have to be included in the study. If, on the other hand, the internal volume is required to be equal, a change in insulation thickness may require adjustments in the physical surroundings of the refrigerator (the other kitchen furniture). If both the internal and the external volumes are required to be equal, obviously no adjustment is possible which can accommodate the change in isolation thickness. This shows that the choice of required functions also determines the possible alternatives, which can be included in the study.

Adjustment by system expansion, as in the examples above, is not always possible. If one is studying only the freezing *or* refrigeration function of a combined freezer-refrigerator (e.g. for inclusion in a life cycle of a food product, which is refrigerated, but not frozen), there is no adjustment in the surroundings, which can adjust for the effect of the combination of the two functions. Thus, the inputs and outputs from the combined freezer-refrigerator must somehow be allocated between the two functions. This may be done based on a measure of the relative energy requirement for the two compartments, also known as the temperature-adjusted volume, calculated as: