Chapter 5
Examples

The purpose of this chapter is to provide useful examples of how one could address important issues such as CE marking and calculating the carbon footprint of products.

Section 5.1 describes conformity assessment requirements, including the CE marking requirement of the Ecodesign directive. An example which demonstrates an Energy Related Product – a complex set top box – has been chosen.

Section 5.2 provides an example of the successful implementation of Ecodesign from industrial practice.

Section 5.3 deals with environmental communication, by demonstrating how to calculate the carbon footprint of a product. The same product addressed in Section 5.1 is used to calculate the carbon footprint.

5.1 Conformity Assessment and CE Marking

Conformity means meeting the requirements specified in law and/or standards. Conformity assessment is any activity concerned with directly or indirectly determining that relevant requirements are fulfilled. Typical examples of conformity assessment activities are sampling, testing, and inspection; evaluation, verification, and assurance of conformity (supplier's declaration, certification); registration, accreditation, and approval as well as their combinations) [12].

CE stands for "**C**onformité **E**uropéene", a French term which means European Conformity. When the CE mark (see Fig. 5.1) is affixed to a product, it indicates that a manufacturer and the product is in compliance with the requirements stipulated in the EU machinery directive [1]. Since the Ecodesign directive was first introduced, environmental issues have been added for products affected by the Ecodesign directive. It is the sole responsibility of manufacturers that any CE

W. Wimmer et al., *ECODESIGN – The Competitive Advantage*, Alliance for Global Sustainability Bookseries 18,
DOI 10.1007/978-90-481-9127-7_5,

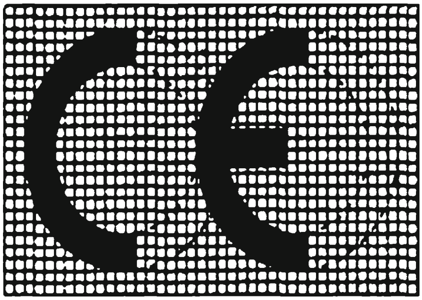


Fig. 5.1 CE Marking

marking on their products meet the legal requirements and they bear ultimate responsibility for the conformity of the product. Environmental properties required can be declared by self-declaration. For technical purposes, self-declaration might not always be enough, i.e. for medical equipment. Then a certificate of a third party might be required.

In this context, conformity assessment relates to the design and production phases of the product. There are eight different conformity assessment procedures or "modules" which cover the design and production phases: internal production control (module A); CE type-examination (module B); conformity to type (module C); production quality assurance (module D); product quality assurance (module E); product verification (module F); unit verification (module G); full quality assurance (module H). The module applied to most ERP is module A, internal production control which covers internal design and production control.

One of the major requirements for manufacturers in fulfilling the CE marking requirements is to draw up a technical file (technical documentation). This document is intended to provide information on the design, manufacture, and operation of the product [2].

In the Ecodesign directive and accompanying implementing measures for a specific product category, it is stipulated that conformity assessment must be carried out and CE marking must be affixed to the product. This implies that the product under the conformity assessment requirement must comply with not only the requirements in the Ecodesign directive, but also in any other relevant directives, such as those related to low voltage devices (LVD) and electromagnetic compatibility (EMC).

5.1.1 Regulations and Studies of the EU About Set Top Boxes (STB)

Investigations on set-top boxes (STB) have led to a regulation on a simple STB [3]. Corresponding studies are available from the EU. Studies are also available for complex STB and regulation is planned [4]. It should also be mentioned that the requirements cover a conformity declaration according to Annexes IV or V of the Ecodesign directive. A copy of this text can be found in Annex 8.

Requirements, according to the Ecodesign directive for a manufacturer, are

- Documentation of the assessment result according to Annexes IV or V
- Conformity declaration according to Annex VI to be documented by
  - (a) Results from Ecodesign activities
  - (b) Comparison of achievements against requirements
- Documentation for recyclers
- Information for customers

Those companies having installed a management system according to Annex V of the Ecodesign directive or have been awarded an European ecolabel for their product are exempted.

To document the requirements for recycling, manufacturer organizations and the European Recycling Association offer standard checklists. Information to customers could be given by means of an environmental product declaration (in accordance with ISO 14025 or, more generally, ISO 14020).

In order to aid in understanding the conformity assessment requirements in the Ecodesign directive, the complex set top box (CSTB) was chosen as an example product for an ERP. A technical documentation file of the CSTB was developed in this section to demonstrate the applicability of the requirements to the CSTB.

5.1.2 Legal Requirements

In the Ecodesign directive, Article 5 stipulates the requirements for the CE marking and the declaration of conformity that an ERP must meet before its placement on the EU market. Of particular importance is the requirement on the declaration of conformity referred in an appropriate implementing measure. Specific elements of the declaration of conformity include according to the Ecodesign directive:

- The name and address of the manufacturer (or authorized representative)
- A description of the model
- The references for the harmonized standards applied, if appropriate
- Other technical standards and specifications used, if appropriate
- Reference to other Community legislation providing for the affixing of the CE mark that is applied, if appropriate
- Identification and signature of the person empowered to bind the manufacturer (authorized representative)

5.1.3 Procedures to Affix CE-marking

Since the implementing measures of the Ecodesign directive require module A for conformity assessment, the related requirements, together with the preparation of a technical documentation file, are discussed here.

Module A refers to internal production control where the manufacturer must [5]:

- Establish a technical documentation file, thereby enabling conformity of the product with the requirements of the directive to be assessed
- Keep the technical documentation file for at least 10 years after the last product has been manufactured
- Keep a copy of the declaration of conformity with the technical documentation
- Take all measures necessary in order that the manufacturing process ensures compliance of the manufactured products with the technical documentation

In general, the technical documentation file consists of two parts: essential technical data and supporting technical documentation.

(i) Essential technical data includes information such as authorized representative in the EU, manufacturer's name and address, manufacturer's declaration of conformity, certificates, product identification/description, list of harmonized standards/specification, and operating instructions.
(ii) Supporting technical documentation includes test plans, test reports, and engineering drawing, etc. [5].

There are two options for an assessment of conformity with the requirements of the applicable implementing measure: internal design control in Annex 4 or management system in Annex 5 of the Ecodesign directive. Both options are essentially the same. Differences between the two reside in which are the responsible party for managing and implementing Ecodesign, the design department or the environmental management department. The choice will be made by individual companies based on their own corporate structure and culture. In this book, internal design control was chosen for the conformity assessment. Key elements of the internal design control are summarized below [7].

A. A general description of the ERP and of its intended use
B. The results of relevant environmental assessment studies which are used by the manufacturer in evaluating, documenting, and determining product design solutions
C. The ecological profile, if required by the implementing measure
D. Elements of the product design specification relating to environmental design aspects of the product
E. A list of the appropriate standards
F. A copy of the information concerning the environmental design aspects of the product provided in accordance with the requirements specified in Annex 1, Part 2

G. The results of measurements on the ecodesign requirements carried out, including details of the conformity of these measurements as compared with the ecodesign requirements set out in the applicable implementing measure

The seven elements listed above comprise the specific requirements for the development of technical documentation file applicable to the ERP.

5.1.3.1 Developing Technical Documentation file of CSTB

A technical documentation file for the conformity assessment of a CSTB to the Ecodesign directive implementing measure is developed below. The conformity assessment procedure used in this example follows the internal design control in Annex 4 of the Ecodesign directive. For each of the seven elements, corresponding information must be filled out to complete the conformity assessment. The assessment results are inserted into the existing technical documentation file of the CSTB to meet the CE marking requirements of the CSTB.

A. A general description of the ERP and its intended use

1. Product definition [6].

   1.1. Definition of General CSTB

   A CSTB is a device that connects to a television and some external source of signal and turns the signal into content then displayed on the screen.

   1.2. Definition of target CSTB related to functions

   The target CSTB consists of the following functions

   - High Definition digital CSTB with internal mass storage media
   - DVB-S and DVB-S2 transmission standards (return path)

   1.2.1 High Definition digital CSTB with internal mass storage media

   High Definition television (HDTV) refers to the broadcasting of television signals with a higher resolution than the Standard Definition television (SDTB) with Hard Disk Drive (HDD)

   1.2.2 Type of Transmission platform (DVB-S receivers)

   Satellite CSTB: A CSTB whose principal function is to receive television signals from satellites and deliver them to a consumer display and/or recording device.

2. Scope definition

   Complex STBs are STBs which allow conditional access. A set-top box is a stand-alone device, using an integral or dedicated external power supply,

for the reception of High Definition (HD) digital broadcasting services satellite and/or terrestrial transmission and their conversion to analogue RF and/or line signals and/or with a digital output signal.
CSTBs might have additional features, such as

– Return path/integrated modem/internet access
– Multiple tuners (for picture-in-picture or to serve several end-devices)
– Recording with internal mass storage media
– Entitlements

Digital receivers with a recoding function based on removable media in a standard library format (DVD, VHS tape, "Blue-ray" disc, etc.) are excluded from the scope, but complex STBs with removable media are included.

2.1 Target CSTB
   – Product name: Complex Set-top Box
   – Weight and volume: 3.712 kg including packaging and 380 × 60 × 300(mm)
   – Functionality: Receiving broadcasts, Personal recording and Multimedia, HD display
   – Company: Marusys (Korea)

   Table 5.1 shows the part list and picture of each part.

3. Intended use
   3.1. Household

   Larger reception installations, such as communal satellite installations, which are not intended to serve one household only.

   3.2. Uses of product
      3.2.1. Transmission platform of media content delivery

      For satellite broadcasting, the signal is broadcast (often encrypted) by the media content provider to the satellite that transmits it back to Earth. The viewers need a satellite dish antenna to receive the signal and a CSTB to control the access to the signal (to decrypt the encrypted signal). The signal can be analogue or digital.

   3.3. Manual for consumer
   The manual for consumers include important information including:

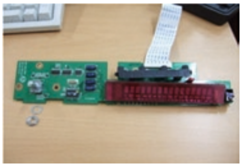
   • Safety instructions – Important notes
   • Controls, displays, and connections
   • How to connect and set-up
   • Remote control information
   • First Installation
   • Operating instructions
   • On-Screen displays
   • EPG – Electronic Programme Guide

Table 5.1 Part list of CSTB

Part list		Quantity	Description
Set top box		1	Product
Packaging	  	1	Package and protect product
Main board		1	Control CSTB functions
SMPS		1	Control power supply
Cover top	 	1	Protect internal part
Panel assembly	 	1	Control function

(continued)

Table 5.1 (continued)

Part list		Quantity	Description
PCB panel assembly		1	Display information of CSTB
Cover back		1	Protect Internal part andventilation
Cable	 	1	Connection part

- Common interface
- Videotext (teletext)
- Edit channel list
- Channel search (channel scan)
- Parental control
- Settings
- Service menu
- Connecting up the video/PVR
- Using the front panel
- Technical appendix
- Short technical guide
- Troubleshooting

B. The results of relevant environmental assessment studies, which are used by the manufacturer in evaluating, documenting, and determining product design solutions

1. Results of typical power consumption

   The available market and product data – typical power consumption values can be estimated. The resulting typical power consumption levels in technical analysis of existing product (task 4) of the preparatory study are presented in Table 5.2.

2. Results of LCA on CSTB

   The total environmental impacts for CSTB according to the EcoReport calculations are listed in Table 5.3.

Table 5.2 Typical on mode and active standby power consumption of CSTBs per functionality

	Typical power consumption (W)	
STB(DVB-C, -S, -T, IPTV)	On mode	Active standby
Basic "complex" STB, including all typical interfaces, digit display, Cl and/or CAM, etc.	10	5
Additional power consumption for	+8	+2
• Hard disk drive	+5	+1
• Second tuner/multiple tuners	+8	+8
• High definition capability	+10	+10
• Return path		

[6]

The use stage impacts on the total energy, electricity, and greenhouse gases for different modes:

– On mode: 55%
– Active standby mode: 45%
– Off mode: <0.1%

Materials acquisition, use, and end-of-life are all relevant. Regarding the on mode and active standby mode, both need further consideration, whereas the off mode is of minor relevance.

Typical power consumption of the existing CSTB gathered through a stakeholder questionnaire – Table 5.4 shows the survey results of the power consumption of CSTB [6].

C. The ecological profile, if required by the implementing measure.

"Ecological profile" means a description, in accordance with the implementing measure applicable to the ERP, of the inputs and outputs (such as materials, emissions, and waste) associated with an ERP throughout its life cycle which are significant from the point of view of its environmental impact and are expressed in physical quantities that can be measured (Ecodesign directive, Article 2 "definitions").

Table 5.5 shows a rough example of an ecological profile format of a product. The best approximation is the scheme from the base cases used for all ERP by the consultants.

There is no requirement to use Table 5.5 for all products but it is part of the investigation methodology published on the homepage of the EU [7]. A standardized methodology is not available. The European Commission is installing a revised LCA method where scientifically agreed impact categories are described.

Since the implementing measure of the CSTB does not require the declaration of the ecological profile of CSTB, there is no need to show the profile here.

In the event the manufacturer wishes to disclose the ecological profile, one can show a carbon profile as shown in Section 5.3 "Carbon footprint, carbon reduction opportunity and carbon management approach using set-top box as an example ERP". The carbon profile in Section 5.3 was developed based on

Table 5.3 Environmental impact of CSTB

Nr	Life cycle impact per product;							Date	Author		
0	Base Case 6: complex STB with HD, HDD, 2nd tuner, return path							0	KSchi		
	Life cycle phases ->		Production			End-of-life					
	Resources Use and Emissions		Material	Manufacturing	Total	Distribution	Use	Disposal	Recycling	Total	Total
	Other Resources and Waste							Debit	Credit		
8	Total Energy (GER)	MJ	519	124	643	109	11,941	121	80	41	12,735
9	of which, electricity (in primary MJ)	MJ	154	30	184	0	11,936	0	35	–35	12,086
10	Water (process)	ltr	289	7	296	0	799	0	31	–31	1,063
11	Water (cooling)	ltr	131	34	165	0	31,827	0	7	–7	31,985
12	Waste, non-haz./landfill	g	17,778	268	18,046	79	14,018	1,806	100	1,206	33,349
13	Waste, hazardous/incinerated	g	538	3	541	2	280	712	39	673	1496
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO_2 eq.	31	8	39	9	521	9	5	4	573
15	Ozone Depletion, emissions	mg R-11 eq.	Negligible								
16	Acidification, emissions	g SO_2 eq.	349	41	389	27	3,077	18	29	–11	3,482
17	Volatile Organic Compounds (VOC)	g	2	2	3	1	5	0	0	0	9
18	Persistent Organic Pollutants (POP)	ng i-Teq	23	4	28	0	79	9	0	9	115
19	Heavy Metals	mg Ni eq.	216	10	226	4	207	34	4	30	467
	PAHs	mg Ni eq.	81	2	82	3	24	0	4	–4	107
20	Particulate Matter (PM, dust)	g	35	11	45	19	66	156	1	155	285
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	222	0	222	0	79	10	20	–10	292
22	Eutrophication	g PO4	5	0	6	0	0	1	0	0	6
23	Persistent Organic Pollutants (POP)	ng i-Teq	Negligible								

Table 5.4 Typical power consumption data of existing CSTB

	Typical power consumption (W)	
STB (DVB-C, -S, -T, IPTV)	On mode	Active standby
Basic "complex" STB, including all typical interfaces, digit display, Cl and/or CAM, etc.	10	4 → 5
Additional power consumption for	+5 → +8+5	+2
• Hard disk drive	+8	+1
• Second tuner/multiple tuners	+10	+8
• High definition capability		+6 → +10
• Return path		

[6]

Table 5.5 An example of an ecological profile format of an ERP (cf. Table 5.3)

Materials
Total (kg) of which
Disposal (kg)
Recycled (kg)
Other resources
Total energy (GJ)
of which, electric (in primary) (GJ)
Water (process) (m^3)
Water (cooling) (m^3)
Waste, non-hazardous/landfill (kg)
Emissions to air
GHG in GWP 100 (t CO_2)
Acidification Potential AP (kg SO_x)
Volatile Organic Compounds VOC (kg)
Persistent organic pollutants PoPs (mg i-Teq)
Heavy metals (mg Ni)
Polyaromatic hydrocarbons PAHs (mg)
Particular matter (dust) (kg)
Emissions to water
Heavy metals (g Hg/20)
Eutrophication (g PO_4)

the method related to the ongoing international standardization work on carbon footprinting [8].

D. Elements of the product design specification relating to environmental design aspects of the product

Energy consumption during the use stage was identified as the most significant environmental aspect; thus, this needs to be improved through product design. Product specifications based on the environmentally significant aspects were developed and are shown in Table 5.6.

Table 5.6 Product design specification related to the significant environmental aspects of CSTB

Life cycle stage	Type of specification		Name of specification	Explanation and value
Product use	Fixed	Power consumption not exceeding 15 W	Indication for energy consumption in the on mode	Typical power consumption (Basic CSTB, HD capability, Return path)
	Fixed	Power consumption not exceeding 9 W	Indication for energy consumption in the standby mode	Active standby mode

[6]

Table 5.7 Standards applied to the development of technical documentation file of CSTB

Standard name	Contents	Application area
EN/IEC 62301:2005	Measurement of electrical power consumption in the stand-by mode	Household Electrical Appliances
IEC 62087:2002/EN 62087:2003	Measurement of the power consumption of digital terrestrial, digital cable, and digital satellite CSTBs	Specific to digital television CSTBs with detailed converge of test signal and external loads
CEA-2013	Measurement and maximum limit of stand-by mode	Specific to digital television CSTBs includes treatment of parasitic peripherals such as security cards
IEC 62430	Environmentally Conscious Design of electro-technical products	

E. A list of the appropriate standards

Appropriate standards applied to the development of this technical documentation file are shown in Table 5.7.

F. A copy of the information concerning the environmental design aspects of the product provided in accordance with the requirements specified in Annex 1, Part 2. (Note: The requirements in Annex 1, Part 2 are requirements relating to the supply of information.) according to the Ecodesign directive.

Figure 5.2 shows the manufacturing process and picture of the CSTB.

The stand-by power consumption of <1 W printed on the receiver packaging is achieved only when the receiver is in stand-by mode with the display switched off. You can perform the setting in the following menu: "Main menu", "Settings", "Customize screen menu", "Front display in stand-by".

Do not switch the receiver off at the power switch directly from the operating mode. This can lead to loss of data and corruption of the software.

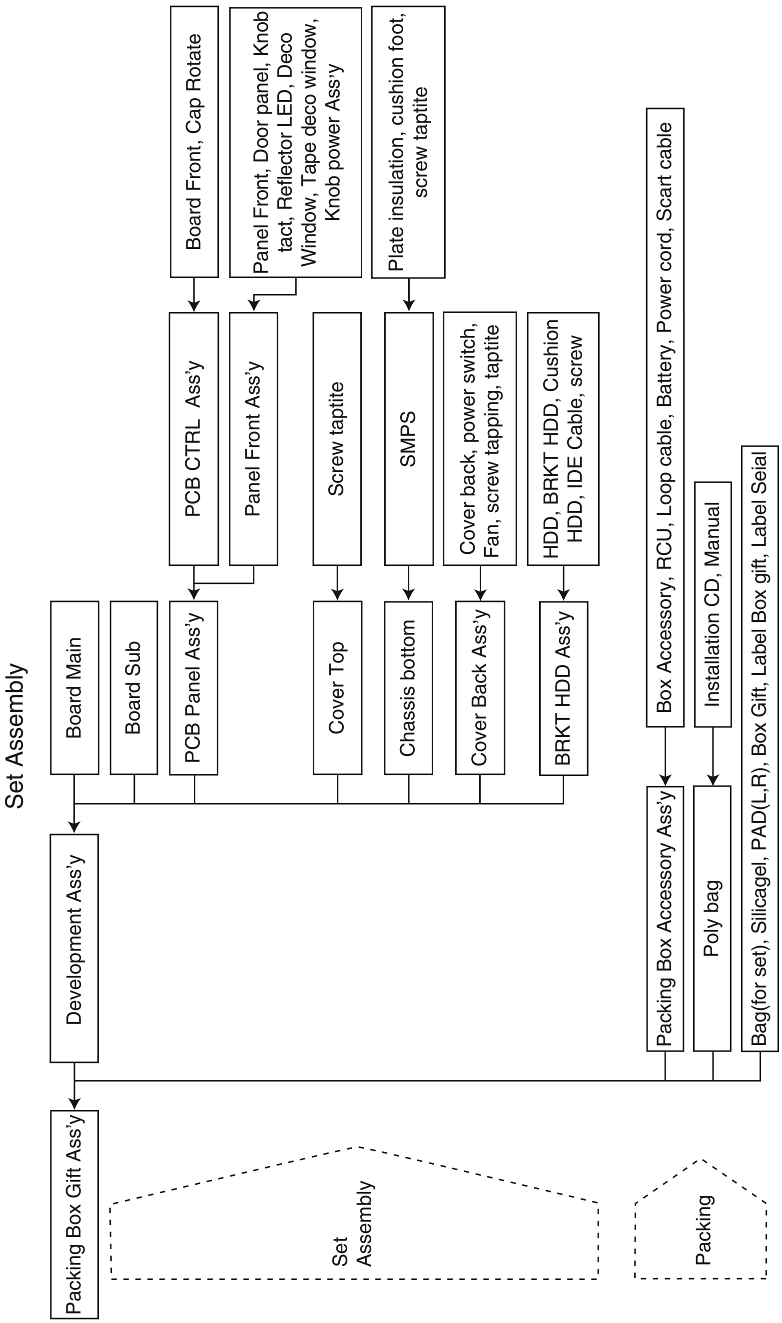
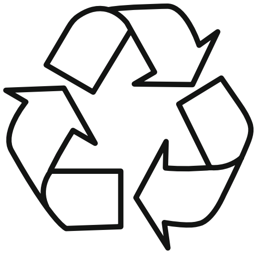


Fig. 5.2 Manufacturing Process of CSTB

Electronic equipment is not domestic waste – in accordance with WEEE directive on used electrical and electronic appliances, it must be disposed of properly.



5.1.4 Used Batteries Are Special Waste!

Do not throw spent batteries into your domestic waste; take them to a collection point for old batteries!

G. The results of measurements on the Ecodesign requirements carried out, including details of the conformity of these measurements as compared with the Ecodesign requirements set out in the applicable implementing measure.

G.1 Ecodesign requirements

Ecodesign requirements of CSTB were met by following the procedure shown in Table 5.8.

5.1.4.1 Measurements Method

Several test methods for the measurement of the energy consumption are shown in Table 5.9 of these methods, EN 62087 was used.

5.1.5 Power Consumption Data of CSTB

Power consumption data of the CSTB is shown in Table 5.10.

Table 5.8 Procedures for meeting the Ecodesign requirements of CSTB

D product design specification	E appropriate standards	G The results of measurements
Energy consumption during the use stage	IEC 62087:2002/ EN 62087:2003 Measurement of the power consumption of digital terrestrial, digital cable, and digital satellite CSTBs	Test results of the energy consumption during the use stage following EN 62087 certified by a laboratory accredited by KOLAS

[6]

Table 5.9 Measurement methods of the energy consumption of an ERP (n/a = not applicable)

	EN 62087	EN 62301	CEA2013-A[a]	CEA 2022
Scope	Specific to digital STBs with detail coverage of test signals and external loads	Not specific to STBs but detailed methodology on low power measurement	Specific to digital STBs	Specific to digital STB whose primary function is video reception and delivery
Measurement modes	Disconnected Off Stand-by passive Stand-by active (low) Stand-by active (high) On (play) On (record)	Stand-by Low Power mode	Sleep	On
Temperatures	15–35°C, with 20°C preferable	23 ± 5°C	22 ± 4°C	n/a
Power supply	Device rated voltage and frequency, ±2%	230 V ac/50 Hz/±1%	115 V RMS ± 3 V 60 ± 3 Hz	n/a
Instrument Accuracy	Not given	P≤10 W → 0.01 W 10 W < P ≤ 100 W → 0.1 W P > 100 W → 1 W	Resolution to be 0.1 W or better True power watt meter preferred	n/a

[a]CEA: The Consumer Electronics Association

Table 5.10 Power consumption of CSTB

Mode of operation	Power consumption (W)	Period (h)	Energy (Wh)
Watching digital broadcast			
- Free to Air broadcast (TV, Radio)	20.1	1.125	22.6
- Pay TV scrambled by conditional access system	21	1.125	23.6
			46.2
Personal Video Recorder			
- Single recording	21.1	1.125	23.7
- Dual recording	21	1.125	23.6
- Playing	20.8	1.125	23.4
- Trick play	21	1.125	23.6
			94.3
Multimedia			
- MP3	19.8	0.45	8.9
- JPEG	19.8	0.45	8.9
- GAME	19.8	0.45	8.9
- VLC streaming	19.8	0.45	8.9
			35.6
Channel search	18.9	0.45	8.5
Stand-by mode	9	14.76	132.8
Off mode	0	0.24	0
			141.3
	Total (per day)	24	317.6
	Total (5 years)	579.6 KWh	

5.2 Example – Siemens Former Mobile Phone Base Station

5.2.1 Introduction

The design of this particular product demonstrates that, not only are environmentally compatible solutions possible, but money can be saved when considering the whole life cycle. The product used in this example is the Siemens former mobile phone station model number 60/61 which is shown in Fig. 5.3. In Section 4.5, the Ecodesign system of Siemens is described in some detail, and serves as an example of a simple design procedure that may be applicable to every SME. Similar design rules as identified in Annex 2a were applied for this solution.

5.2.2 Target

The target of the design solution was to address the main environmental impacts: energy consumption, resources required, and radiation impact. While the radiation was not particularly high, it was reduced because of general public concern.

Fig. 5.3 Base Station BS 60/61

5.2.3 Examples for Improved Environmental Solutions

5.2.3.1 The Cabinet (Containing Electronics)

When considering the environmental improvement opportunities for a cabinet, there are two areas in which environmental optimization can be pursued: (i) the structure or design of the cabinet and (ii) the materials used.

In terms of structure, one can optimize the use of the *volume*. Such a volume optimization may not always appear to make sense for industrially applied products if resource costs do not play a role. However, in this case, a total volume reduction could be achieved and, within the same volume, eight transmission units could be placed instead of six and resources were therefore saved.

The selection of the housing material offers different optimization opportunities, depending on climatic conditions and different marking technologies. Stainless steel was selected for the housing in this case. While stainless steel is more expensive than other materials, it is inherently resistant to corrosion and fire, it does not change colour, and inscription can be done by a laser. The forerunner previous model consisted of chemically oxidized aluminium which was also coated. The marking was printed, which required additional chemicals. A total cost reduction of 50% was achieved in comparison with the previous model.

Fans are often required for cooling electronic components as elevated temperatures can reduce reliability. The right structure, or design, can be enough to create “natural” circulation of the heated air, thereby reducing or eliminating the need for a fan. The climatic conditions in the location where the base stations are to be located are often not known in advance, or are often not considered or investigated. Therefore, it was decided to have one “robust” model for a variety of applications. For an outdoor application of a mobile phone base station, air conditioning in up to 55°C outside temperatures is possible without the need to include active cooling. The energy consuming fan is thereby avoided.

5.2.3.2 Energy Consumption

As energy costs have dramatically increased over the last few years, energy consumption is increasingly of interest. For a telecom provider, the number of stations (many thousands) can be multiplied by the energy consumption of each piece of equipment to determine the total costs. Such an investigation is also necessary to determine the environmental impacts of such equipment as energy consumption and the emission of greenhouse gases can be easily correlated. As a result, energy consumption has become a political issue as well. For the BS 60/61, when compared to the former product generation, a 35% reduction of the power uptake could be achieved. For the first year of sales alone, the energy savings equate to a reduction of some 57,000 t of CO_2 and about €6 million of cost reduction for customers. This would be like conserving, or simply not using 503 train wagons of coal to generate electricity if the tons of CO_2 saved are converted to a standard load of a coal wagon.

5.2.3.3 Electronic and Software Oriented Tools

In the case of a mobile phone base station, the tele-recognition of the "Electronic serial number" can supply all of the configuration values and can enable the optimization of service intervals. The environmental benefits are reduced travel for service engineers and stability of operating characteristics (especially energy consumption which stays at the same level). In total, tele-recognition results in reduced energy consumption and lower use of auxiliaries and resources.

Reduced expenditures for administration and maintenance with implementation, documentation, service, software updates, and inventories by customers can be achieved by the software via the internet. Also, recycling of the plant can be planned or the technological or software state of the system can be checked: Is the energy consumption too high compared with a new product generation or could new software be implemented which saves more energy?

The role of software for energy consumption is frequently underestimated. Much more energy could be reduced if the software was optimized, e.g., by avoiding battery loading or stand-by. Additionally energy or resource saving components, like capacitors instead of batteries, could be used.

5.2.3.4 Improved Reception Sensitivity

The discussion about radiation protection will undoubtedly continue. Optimization is electronically possible. A 37% reduction of transmission impact of all cellular phones in the net can be achieved with such a base station. In the end, for the users of cellular phones, a reduced radiation impact is the result. As a further benefit, the application time of the phone is increased as the life span of the batteries of the cellular phones became longer.

5.2.3.5 Innovative Ideas Can Be Found Everywhere

As mentioned above, for outdoor applications no active cooling is necessary. The advanced cooling by membrane filter was the innovative approach that received an EU patent. The package density was increased for the cabinets and racks, also the cooling was improved. The following savings were achieved because of the new heat exchanger system:

- 7 K better heat balance
- MTBF – improvement 31%
- Cost reduction 33%
- Weight reduction 50%
- Volume minus 38%
- Energy consumption: –180 W

As the product optimization was often only promoted for cost reduction in manufacturing processes or the application of low-cost parts, high levels of innovation for energy and resource reduction are still possible.

5.2.3.6 Parts and Types Reduction

In every cost reduction programme, the reduction of parts and types is reviewed. From an environmental point of view, such a reduction process is critical. In a normal parts and types reduction programme, there is a distinction made between the 20% most applied components or products and the remaining 80% which should be reduced or omitted. But from the environmental point of view, the target could be to reduce the type of materials used to one kind only (e.g. one type of metal or plastic for all). This target can be approached by evaluating the materials to be substituted and, for example, replacing more expensive high impact plastic with low impact ones with better environmental performance. A further optimization could be to combine several parts into one part (e.g. in an injection molding process) with the result being fewer parts and ideally made from only one type of plastic or metal. Therefore, the target is much more ambitious than in normal types and parts reduction exercises. The resulting environmental impact and the costs can be much lower than before. Assembly and disassembly costs will be reduced and recycling costs will be replaced by earnings.

If we look at the old version of a sub-rack in the mobile phone base station (Fig. 5.4) where the printed wiring boards were inserted, we find 66 different parts, four different materials and 25% more space required than for the new solution (Fig. 5.5).

The key features of the new sub-rack are:

– Number of different parts is now 17 (4 sheet metals, 1 support part, 12 screws).
– Design complexity: four different parts.
– Integrated parts: printed wiring board, air conditioning lattice, fixation of backplane positioning.
– Environmental advantage: one common material for all. Cost: 78% less than the former sub-rack.

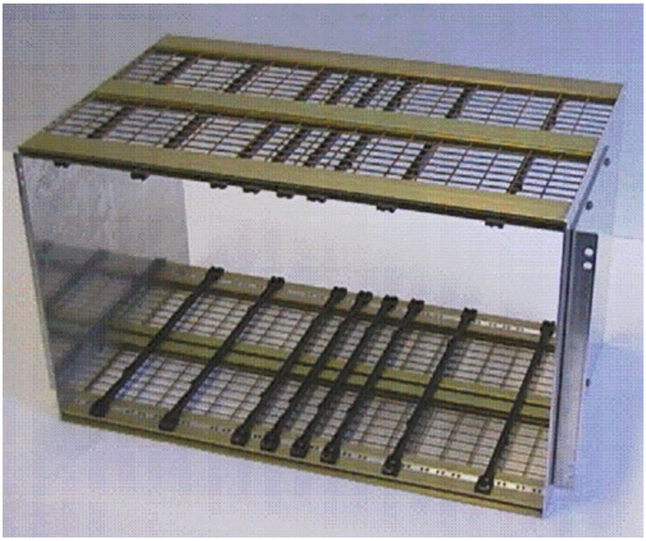


Fig. 5.4 Old solution (sub-rack)

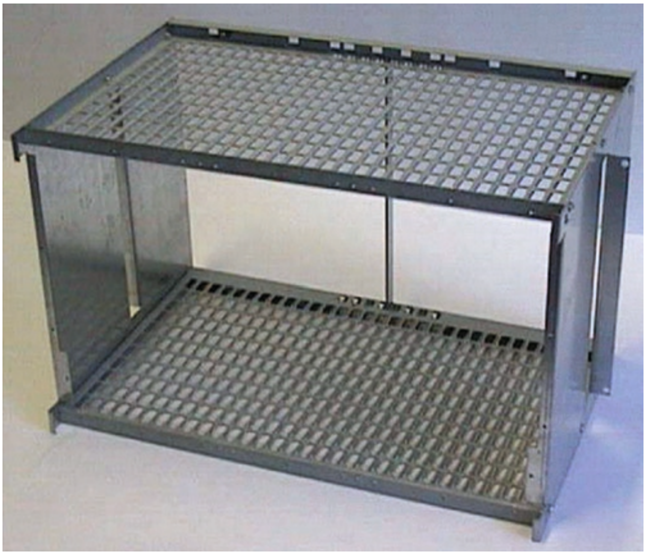


Fig. 5.5 New solution (sub-rack)

Here a discussion between quality engineers and environmental engineers becomes interesting – how is quality determined? The "Quality" of the old solution may be 100% but this won't be 100% satisfactory if the complexity of the old solution is evaluated.

5.2.4 Summary: Results for Mobile Phone Base Station

Sensitivity: + 2 dB higher = Power consumption 37% less is possible in mobile phone
New cooling system: (33% less cost)

- Cooling by air without active cooling
- Cooling with membrane filter (= no heat exchanger)

Front: Noble steel (frottage structure), laser inscription: 100% recycling possible
Subrack:

- New Solution: one material, only 17 parts, ca. 80% lower cost
- Old solution: 66 parts, four different materials, 25% more space required

Service: Costs reduced by remote control
Packaging: Now plug & play from factory (= less packaging); only wood as packaging material and multiuse packaging
Total product: Nearly 100% recycling possible. High cost reduction for the overall product achieved

5.3 Carbon Footprint, Carbon Reduction Opportunity, and Carbon Management Approach Using Complex Set-Top Box as an Example ERP

In accordance with the procedures and methods described in Section 2.3.1.3, a carbon footprint of a product was developed, carbon reduction opportunities were identified, and a carbon management approach was discussed using a complex set-top box (CSTB) as an example ERP.

5.3.1 Developing Carbon Footprint

In order to develop the carbon footprint, the CSTB was disassembled into major parts and subparts and the weight of each part and subpart measured. The Bill of Material (BOM) data for the CSTB was used to aid in the disassembly. The information gathered in this step was used to formulate the product structure by identifying the various processes, ranging from the use of raw materials to the manufacturing stage of the CSTB. In addition, scenarios for the distribution, use, and end of life cycle stages were made based on realistic data and reasonable assumptions. This included data for the transport mode and distance during the distribution stage, time for the use of the product during the use stage, and the collection distance, mode of recycling and disposal of the product during the end of life stage. Combining both product structure and scenarios comprised the system boundary of the CSTB. This process is often termed “product modelling” and in this case the result provided a basis for the development of the carbon footprint and subsequent identification of the carbon reduction opportunities, as well as an approach for the carbon management of the product. The system boundary of the CSTB is shown in Fig. 5.6.

According to the system boundary, all of the materials used for the six main components were considered. No cut-off was applied since it was possible to identify all materials. Table 5.11 is the material composition of the CSTB based on the BOM. In addition, it includes the GHG emission factors of each material. The factors were calculated based on the method in the IPCC Guideline [9] by processing the LCI data of each material in the Ecoinvent v 2.1 [10] and other relevant databases.

There are several processes involved in the manufacturing of the parts and the product itself. They are manual insert, auto insert and surface mounting technology (SMT) for the production of printed wiring boards (PWB), and set assembly of the CSTB. Data for the PWB and development assay are site-specific data. In addition, there were inputs into the manufacturing processes, such as steam and hot water. However, their consumption was negligible compared with other input. Table 5.12 shows the energy consumption data in the manufacturing processes.

Data for the distribution stage includes transportation from the CSTB assembly plant located in Dongtan, Korea to a port in Busan by truck and then to Denmark by sea. Table 5.13 shows the scenario for the distribution stage of the CSTB and the GHG emission factors for the different transport modes.

For the use stage of the CSTB, the electricity consumption can be calculated assuming that the use pattern of the CSTB is the same as the standard use pattern defined by Version 2.0 of the ENERGY STAR Program’s “Requirements for Set-Top Boxes” [11]. Based on this assumption, the daily use pattern of the CSTB is 9 h in on mode, 14.76 h in standby mode, and 0.24 h in off mode, and the lifetime of the CSTB is 5 years. Table 5.14 shows the energy consumption data during the use stage of the CSTB.

The scenario for the end-of-life stage is based on the nature of the material: recyclable, combustible, and inert (neither recyclable nor combustible). As shown in Table 5.15, the CSTB consists of 67.2% recyclable materials, 27.4% combustible materials, and 5.4% inert materials. These figures, however, are theoretical because not all CSTB discarded are collected. Thus, a 75% recovery rate of CSTB in the EU’s WEEE directive was assumed to apply. As such, 25% of the CSTBs discarded are assumed to be unaccounted for. In other words, the whereabouts of the unrecovered 25% of CSTBs is unknown. Table 5.15 shows the end-of-life stage scenario with the GHG emission factors of each material.

Summing up all of the data over all the life cycle stages of the CSTB constitutes the product modelling result of the CSTB, and the result is shown in Table 5.16. Normally material, energy, process, transport, and activity data are termed inventory data.

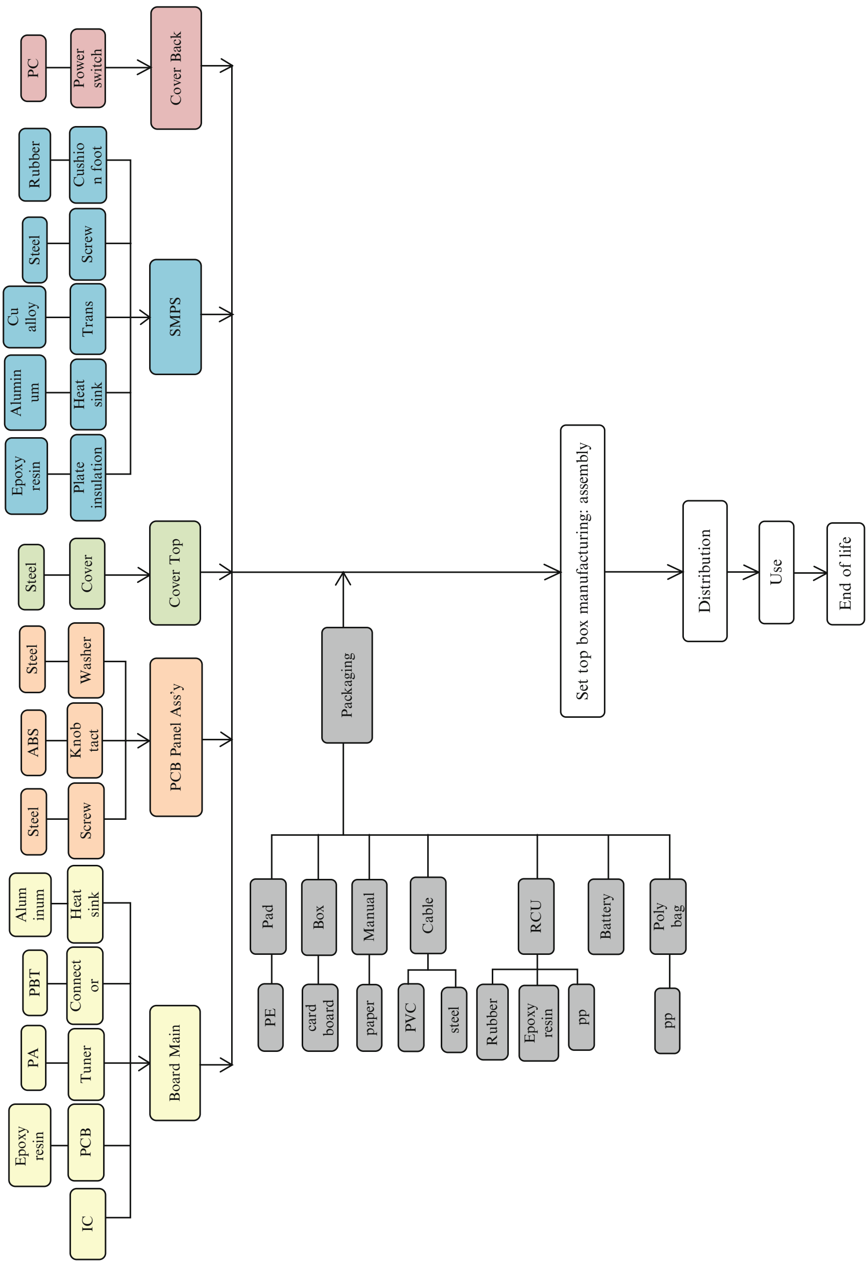


Fig. 5.6 Product system boundary of a CSTB

Table 5.11 Composition of the materials with the corresponding GHG emission factors of the CSTB

Component name	Material	Mass (kg)	GHG emission factor (kg CO_2-eq/kg material)[a]
Board main	Epoxy resin	0.406	6.7304
	PBT (Polybutylene terephthalate)	0.1	2.7011
	PA (polyamide 66)	0.052	8.0191
	Aluminium	0.014	12.376
	IC (integrated circuit component)	0.004	1012.4
PWB(printed wiring board) Panel Assembly	ABS (Acrylonitrile butadiene styrene copolymer)	0.148	4.4031
	Steel	0.0187	4.4768
Cover top	Steel	1.1247	4.4768
SMPs	Epoxy resin	0.284	12.376
	Cu alloy	0.07	1.8926
	Aluminium	0.048	12.376
	Rubber	0.02	2.6531
	Steel	0.007	4.4768
Cover back	PC (Polycarbonate)	0.01	7.7876
Packaging	Cardboard (corrugated)	0.632	1.1403
	Paper	0.24	1.6851
	PVC (Polyvinyl chloride)	0.17	1.9981
	Steel	0.182	4.4768
	Rubber	0.02	2.6531
	Epoxy resin	0.014	6.7304
	PP (polypropylene)	0.042	1.9825
	Battery (component)	0.016	101.84
	PE (polyethylene)	0.088	1.9485 (2.702)
	Silica gel	0.002	2.7091

[a]Derived from the LCI database, Ecoinvent v 2.1 following the IPCC 2007 calculation method

Table 5.12 Manufacturing stage energy consumption data of the CSTB

Manufacturing process	Electricity (kWh)	GHG Emission factor (kg CO_2-eq/kWh Electricity)[a]
Manual insert process	0.45	0.495
Auto insert processing	7.5	
SMT processing printed wiring board mounting facilities	8	
Set assembly	0.14	

[a]Derived from the Korean LCI database, following the IPCC 2007 calculation method

Table 5.13 Distribution stage scenario of the CSTB and the GHG emission factors

Transport mode	Distance (km)	GHG Emission factor (kg CO_2-eq/t-km)[a]
40 t truck (from plant to Busan) transport, lorry >32 t, EURO5	364	0.10402
Vessel (from Busan to Denmark) Transport, transoceanic freight ship	20,555	0.010749

[a]Derived from the LCI database, Ecoinvent v 2.1 following the IPCC 2007 calculation method

Table 5.14 Use stage data of the CSTB

	Power consumption (W)	Hour (h)	Energy (Wh)
On mode	20.28	9	182.52
Stand-by active mode	9	14.76	132.84
Off mode	0	0.12	0
	Total (per day)	24	315.36

Table 5.15 End-of-life stage data of the CSTB with the corresponding GHG emission factors

Mode of operation	Material	Weight (kg)	GHG Emission Factor (kg CO_2 – eq/kg)[a]
Incineration (27.4%)	Epoxy resin (disposal, plastic, consumer electronics, 15.3% water, to municipal incineration, CH)	0.704	3.029
	Rubber (disposal, rubber, unspecified, 0% water, to municipal incineration, CH)	0.04	3.1388
	PVC (disposal, polyvinylchloride, 0.2% water, to municipal incineration, CH)	0.17	2.2611
	PBT (disposal, Polybutylene terephthalate, 0.2% water, to municipal incineration, CH)	0.1	2.033
	IC (disposal, capacitors, 0% water, to hazardous waste incineration, CH)	0.004	2.5017
Recycle (67.2%)	Steel[+]	1.3324	−1.69
	Copper alloy (copper, secondary, from electronic and electric scrap recycling, at refinery, SE)	0.07	0.10399
	Al (aluminium, secondary, from new scrap, at plant, RER)	0.062	0.41924
	PC[+]	0.01	−0.332
	ABS[+]	0.148	−0.332
	Card board (corrugated board, recycling fibre, single wall, at plant, RER)	0.632	0.98533
	Paper (paper, recycling, with de-inking, at plant, RER)	0.24	1.5564
Landfill (5.4%)	Silica gel	0.002	0
	PE[+]	0.088	0.491
	PP[+]	0.042	0.415
	PA (Nylon 66)	0.052	0.0897
	Battery	0.016	0.797

[a]Derived from the LCI database, Ecoinvent v 2.1 and BUWAL250 (marked [+]) following the IPCC 2007 calculation method

Table 5.16 Product modelling result of the CSTB

Life cycle stage	Inventory data	Data source
Use of raw materials	Steel (1332.4 g), Epoxy resin (704 g), Cardboard (632 g), Paper (240 g), PVC (170 g), ABS (148 g), PBT (100 g), Copper alloy (70 g), Aluminium (62 g), PA (52 g), PC (10 g), PE (88 g), Rubber (40 g), PP (42 g), Silica gel (2 g), IC (4 g), Battery: AAA size(16 g)	Measured
Manufacture	Man Insert (0.45 kWh), Auto Insert (7.5 kWh), Surface Mounting Technology (8 kWh), Set assembly (0.14 kWh)	Measured
Distribution	Distance: 364 km by 40 t truck (from plant to port), 20 555 km by vessel (from Busan to Denmark)	Measured
Use	Energy consumption (5 years): 575.5 kWh	Scenario
End of life	Recycle: [Steel (1332.4 g), Cardboard (632 g), Paper (240 g), ABS (148 g), Copper alloy (70 g), Aluminium (62 g), PC (10 g)] × 0.75	Scenario
	Incineration: [Epoxy resin (704 g), PVC (170 g), PBT (100 g), Rubber (40 g), IC (4 g)] × 0.75	
	Landfill: [Silica gel (2 g), PE (88 g), PP (42 g), PA (52 g), Battery (16 g)])] × 0.75	

The next step is to calculate the GHG emissions from each life cycle stage shown in Table 5.16. This is determined by taking the inventory data in Table 5.16 and multiplying by the corresponding GHG emission factor. Fig. 5.7 shows the calculation procedure.

The GHG emission results of the CSTB calculated in Fig. 5.7 are shown in Table 5.17.

The CO_2 equivalent results in Table 5.17 have two applications. One is for the development of the carbon profile of the product and the other is for the identification of the carbon reduction opportunities of the product over its entire life cycle. As for the carbon profile, the Table 5.17 results can be envisaged as the carbon profile of the product. Depending on the definition of the carbon footprint, a single score which is the sum of all the CO_2 equivalent values in Table 5.17 can be considered as the carbon footprint of the product. In this case, the carbon footprint of the CSTB is 318.8 kg CO_2-eq.

The carbon reduction opportunity can be identified by applying the contribution analysis method to the carbon footprint results in Table 5.17. Every entry in each cell of the carbon footprint matrix is divided by the total sum of the CO_2 equivalent value (318.8 kg CO_2-eq) and expressed as the percentage value. The percentage value of each entry represents the relative contribution of the entry to the total CO_2 equivalent value of the product. Any contribution from an entry greater than x%, say 1%, can be used as a criterion for selecting the significant parameters requiring improvement. Applying this criterion to the results in Table 5.17, one can choose significant parameters which offer opportunities for carbon reduction. They include the use stage, manufacturing stage, and the steel used during the use of raw material stage of the product.

I. Calculation for the use of raw materials stage (extraction of resources from nature to production of raw and ancillary materials)

GHG emissions of the use of raw materials = $EF_{epoxy\ resin}$/kg x 0.704 kg/epoxy resin + EF_{PBT}/kg x 0.1 kg/PBT +EF_{PA}/kg x 0.052 kg/PA + EF_{steel}/kg x 1.3324 kg/steel + $EF_{Cu\ alloy}$/kg x 0.07 kg/Cu alloy + $EF_{aluminium}$/kg x 0.062 kg/aluminium + EF_{PC}/kg x 0.01 kg/PC + EF_{ABS}/kg x 0.148 kg/ABS + $EF_{cardboard}$/kg x 0.632 kg/cardboard + EF_{paper}/kg x 0.24 kg/paper + EF_{PVC}/kg x 0.17 kg/PVC + EF_{PE}/kg x 0.088 kg/PE + EF_{Rubber}/kg x 0.04 kg/Rubber + EF_{PP}/kg x 0.042 kg/PP + EF_{IC}/kg x 0.004 kg/IC + $EF_{Battery}$/kg x 0.016 kg/Battery + $EF_{Silicagel}$/kg x 0.002 kg/Silicagel

II. Calculation for the manufacturing stage

GHG emissions of the manufacture stage = $EF_{electricity}$/kWh x (0.45 kWh/ manual insert process + 7.5 kWh/ auto insert process + 8 kWh/ SMT process + 0.14 kWh/set assembly process)

III. Calculation for the distribution stage

GHG emissions of the distribution stage = EF 40 ton truck/(ton-km) x distance travelled (364 km) x set-top box weight(3.7124kg) x 1ton/1000kg + EF vessel/(ton-km) x distance travelled (20555km) x set-top box weight(3.7124kg) x 1ton/1000kg

IV. Calculation for the use stage

GHG emissions of the product use stage = $EF_{electricity}$/kWh x 0.31536 kWh/day x 1825 day

V. Calculation for the end of life stage

GHG emissions of the end-of-life stage = ($EF_{incineration,\ epoxy\ resin}$ / kg x 0.704 kg/epoxy resin + $EF_{incineration,\ PVC}$ / kg x 0.170 kg/PVC + $EF_{incineration,\ rubber}$ / kg x 0.04 kg/Rubber + $EF_{incineration,\ IC}$ / kg x 0.004 kg/IC + $EF_{incineration,\ PBT}$ / kg x 0.1 kg/PBT + $EF_{recycling,\ steel}$ / kg x 1.3324 kg /steel + $EF_{recycling,\ copper\ alloy}$ / kg x 0.07 kg/copper alloy + $EF_{recycling,\ Al}$ / kg + 0.062 kg/Al + $EF_{recycling,\ PC}$ / kg x 0.01 kg/ PC + $EF_{recycling,\ ABS}$ / kg + 0.148 kg/ ABS + $EF_{recycling,\ card\ board}$ / kg x 0.632 kg/card board + $EF_{recycling,\ paper}$ / kg + 0.24 kg/paper + $EF_{landfill,\ silicagel}$ / kg + 0.002 kg/Silicagel + $EF_{landfill,\ PA}$ / kg + 0.052 kg/PA + $EF_{landfill,\ PE}$ / kg x 0.088 kg/PE + $EF_{landfill,\ PP}$ / kg + 0.042 kg/PP + $EF_{landfill,\ battery}$ / kg x 0.016 kg/Battery) x 0.75

Fig. 5.7 The calculation procedure of the GHG emissions of the CSTB. Note: EF=emission factor

The carbon footprint in Table 5.17 can also be plotted with respect to the life cycle stages as shown in Fig. 5.8. The use stage was identified as the most significant life cycle stage followed by the use of raw material stage. Both life cycle stages offer carbon reduction opportunities.

Carbon management means the control of the GHG emissions of materials, parts, processes, and activities of a product over its entire supply and value chain. The carbon reduction opportunities identified above show which materials, parts, processes, and/or activities should be controlled and managed. The practical means

Table 5.17 The GHG emissions of the CSTB (kg CO_2-eq/fu)

Use of raw materials		Manufacture		Distribution		Use		End of life		
Materials	GHG	Manufacture	GHG	Delivery	GHG	Use	GHG	End of life		GHG
Steel	5.96E + 00	Manual insert	2.23E – 01	By 40 t truck	1.41 – 01	Electricity	2.85E + 02	Waste (incineration)	Epoxy resin	1.60E + 00
Epoxy resin	4.74E + 00	Auto insert	3.71E + 00	By vessel	8.20 – 01				Rubber	9.42 – 02
									PVC	2.88 – 01
ABS	6.52 – 01	Surface mounting technology	3.25E + 00						PBT	1.52 – 01
PBT	2.70 – 01	Develop assembly	6.93 – 02						IC	7.51 – 03
Copper alloy	1.32 – 01							Recycle	Steel	–1.69E + 00
Aluminium	7.67 – 01								Copper alloy	5.46 – 03
PA	4.17 – 01								Al	1.95 – 02
PC	7.79 – 02								PC	–2.49 – 03
Card board	7.21 – 01								ABS	–3.69 – 02
Paper	4.04 – 01								Card board	4.67 – 01
PVC	3.40 – 01								Paper	2.80 – 01
PE	1.71 – 01							Landfill	Silica gel	0.00E + 00
Rubber	1.06 – 01								PE	3.24 – 02
PP	8.33 – 02								PP	1.31 – 02
IC	4.05 – 00								PA (Nylon 66)	3.50 – 03
Battery	1.63E + 00								Battery	9.56 – 03
Silicagel	5.42 – 03									
Total	20.5296		11.2183		0.9608		284.8874			1.2443

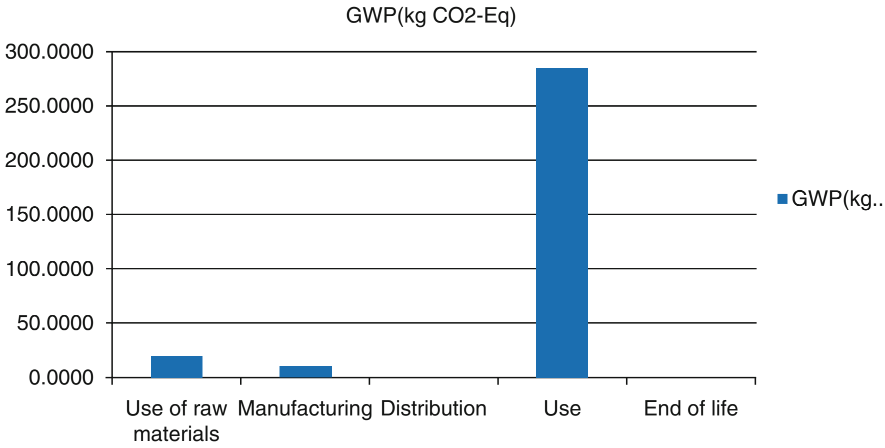


Fig. 5.8 Carbon footprint per life cycle stage of CSTB

for such control is to manage the materials and parts suppliers. Existing supply chain management systems can be utilized for this purpose. As to the control and management of the processes and activities, consumer education, together with appropriate governmental intervention such as carbon taxation or carbon labelling, could be considered.