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Ecodesign Tool Box for Energy-using Products (EuPs)

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Ecodesign Tool Box

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Introduction

This project was funded by the SME Development Fund of the Trade and Industry Department, Hong Kong Special Administrative Region Government and implemented by the Green Manufacturing and Eco-Design Research Group of The Hong Kong Polytechnic University.

Although ecodesign process can generally follow the international standard, IEC CDV 62430, the ecodesign toolbox is developed with the aim of assisting Small and Medium Enterprises (SMEs) in Hong Kong electronic and electrical industries to achieve more straight-forward and better implementation of ecodesign. In the process of complying with the ecodesign requirements of EuP directive, the toolbox can be used as a manual including specific elements and case studies which the local companies can refer to. This toolbox shall be applied with "Step by step conformity assessment procedures" also developed under this project.

In particular, the publication of the ecodeisgn toolbox is a remarkable milestone of the project to provide SMEs in Hong Kong electronic and electrical industries updated demonstration of leading methodologies in compliance of EuP ecodesign requirements. Related information can also be reviewed through website.

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1 MET Matrix

1.1 Background

MET Matrix is a qualitative method which was developed by Hans Brezet and Caroline van Hemel in 1997 in an ecodesign project in the Netherlands. The main purpose of this method was systematically to assess and prioritize the environmental impacts of products in relation to the whole product life cycle. It is a simple method that can save a vast amount to time and money. MET matrix can also be used specifically to perform weak-point analysis and to identify the potential of environmental improvements.

1.2 Evaluation method

To categorize the complicated environmental effects were easily during assessment, environmental problems are grouped into three main areas based on the input and output analysis. They are the material cycle (M), energy use (E) and toxicity emissions (T). The product life cycle is also divided into five life cycle stages: production and supply of materials and components, in-house production, distribution, utilization (including operation and serving), and end-of-life system (including recovery and disposal).

MET matrix is divided into three columns and five main rows. The three columns represent the environmental aspects while the five rows represent the product life cycle stages. The table below shows a typical MET matrix format.

Table 1.1 MET matrix format

		Material Cycle (input/output)	Energy Use (input/output)	Toxic Emission (output)
Raw material acquisition				
Manufacturing				
Distribution				
Use	Operating			
	Servicing			
End-of-life system	Recovery			
	Disposal			

The first column in the MET matrix is to record the environmental impacts which are related to the input and output of materials in all five life cycle stages. It is suggested to include some figures, values or examples for the application of non-renewable materials, incompatible materials and inefficient use or non-reuse of materials or components. Energy consumption in different activities, such as product manufacture, transportation to customer, operating usage, maintenance and recovery of products, is listed in the energy use column. For instance, material inputs with extremely high energy content are recorded in the first row of this column. On the other hand, the column for toxic emissions was specially used to identify the toxic emissions to land, water and air along each stage of the product life cycle.

1.3 Result interpretation

After filling in the matrix, some impact indicators (as below) are used to evaluate the environmental impacts for the product.

Table 1.2 The list of impact indicators usually used in MET matrix

Measurement		
Impact Indicator	Unit	Description
Raw material depletion (RMD)	$year^{-1}$	Depletion of natural resources.
Energy depletion (ED)	MJ	Consumption of energy.
Water depletion (WD)	m^3	Consumption of water.
Global warming potential (GWP)	g of CO_2	Contribution to the global warming of the atmosphere by the release of specific gases.
Ozone depletion(ODP)	g of CFC_{-11}	Contribution to the depletion of the atmospheric ozone layer by the release of specific gases.
Photochemical ozone depletion (POD)	g of C_2H_4	Potential creation of tropospheric ozone by the release ofspecific gases which will become oxidants in the low atmosphere under the action of the solar radiation.
Air acidification (AA)	g of H^+	Air acidification by gases released to the atmosphere.
Air toxicity (AT)	m^3 of bad air	Air toxicity in a human environment.
Water toxicity (WT)	m^3 of bad water	Water toxicity in a human environment.
Water eutrophication (WE)	g of PO_4^{3-}	Enrichment in nutritive elements of lakes and marine water by the release of specific substances in the effluents.
Hazardous waste production (HWP)	kg	Quantity of hazardous waste produced for a given product.

The selection of the impact indicator depends on the environmental impact that is going to be assessed. Global warming potential expressed in CO_2 equivalent value is one of the impact indicators that can be used to convert MET matrix data to environmental related information.

1.4 Points to be noted

Before filling in the matrix, it is suggested that several aspects are considered. The design team should divide their analysis into three parts:

- Define product system boundaries
- Perform a needs analysis
- Perform functional product analysis

Matrices

Ecodesign not only focuses on the physical product, but is also concerned with other products and consumables which are necessary for the physical product to function properly over the whole life span. Therefore, it is important to define the boundaries for studying the product system. After defining the product system, a needs analysis is performed to check whether the actual product meets the needs and to test the effectiveness of the product boundaries.

If the environmental effects of particular subassemblies or components are significant, it is recommended using a separate MET matrix for investigation. When the system boundaries are ascertained, the practitioners then can perform the functional product analysis. This analysis begins with a discussion of the strengths and weaknesses of the product features, for example, the product energy usage, product lifetime, and causal factors of product failure.

Ecodesign Checklists can be used as a reminder for practitioners that for environmental impacts they may miss. In the next step, a MET matrix is completed in order to perform the functional product analysis analytically. The environmental impacts are identified by filling is the relative environmental impact indicator in the matrix. Lastly, the importance of environmental impacts is prioritized according to heavy, medium and light effects, based on the total value of the impact indicator.

1.5 Example

The following example demonstrates how to use MET matrix to assess and prioritize the environmental impact of a toaster.

Step 1: Construct a MET matrix for toaster. Specify input/output data of material cycle, energy use and toxic emissions in the applicable life cycle stage.

Figure 1.1 The toaster

Table 1.3 MET matrix of the toaster

		Material Cycle (input / output)	Energy Use (input / output)	Toxic Emission (output)
Raw material acquisition		PP: 430g Steel Ni-PTD: 30g PCB Assy: 124g PVC: 130g Steel: 341g Chrome plated steel wire: 76.2g Mica sheet: 54g Cardboard: 205g		
Manufacturing			Electricity housing: 0.8kWh Packaging: 0.2kWh Heater: 2kWh	
Distribution			Ship: 2,000km Truck: 500km	
Use	Operating		For 750 uses: 20.625kWh	
	Servicing			
End-of-life system	Recycling	PP: 215g PVC: 65g Cardboard: 102.5g Steel: 371g Chrome: 76.2g Mica sheet: 54g		
	Disposal	PPP: 215g PVC: 65g Cardboard: 102.5g PCB: 124g		

Step 2: Convert the input/ output data into CO_2-eq value in MET Matrix.

As the units of each input and output are different, they need to be standardized to the same unit. For example, the conversion of PP in the material stage:

According to the database of the Ajou University Eco-Product Research Institute, the carbon footprint of PP is 1.37E+ 00 kg CO_2-eq / kg.
Therefore, the CO_2 eq-value of PP is:

(430/1000) X 1.37E+00 = 0.5891 kg CO_2-eq / kg

Table 1.4 Conversion of the input/output data of the toaster into CO_2-eq value in MET Matrix.

		Material Cycle (input / output)	Energy Use (input / output)	Toxic Emission (output)
Raw material acquisition		PP: 0.5891 Steel Ni - PTD: 0.0132 PCB Assy: 1.2648 PVC: 0.1742 Steel: 6.9905 Chrome plated steel wire: 0.1372 Mica sheet: 0.2792 Cardboard: 0.205		
Manufacturing			Electricity housing: 0.3968 Packaging: 0.0992 Heater: 0.992	
Distribution			Ship: 1.44E - 03 Truck: 0.208	
Use	Operating		For 750 uses:10.23	
	Servicing			
End-of -life system	Recycling	PPP: - 0.1574 PVC: - 0.0488 Cardboard: 0.1195 Steel: - 137.78 Chrome: 347.472 Mica sheet: - 247.32		
	Disposal	PP: 0.6887 PVC: 0.0923 Cardboard: 0.0636 PCB: 0.1195		

Step 3 Calculate the total value of CO_2-eq value for all product life cycle stages and environmental aspects.

Product life cycle stages

- Raw material acquisition: 9.65 kg CO_2-eq
- Manufacturing: 1.49 kg CO_2-eq
- Distribution: 0.209 kg CO_2-eq
- Use: 10.2 kg CO_2-eq
- End of life: -36.75 kg CO_2-eq

Environmental aspects

- Material: -27.1 kg CO_2-eq
- Energy: 11.9 kg CO_2-eq
- Toxicity: 0 kg CO_2-eq

Step 4 Result interpretation.
From the results, use stage and the energy aspect can be interpreted as most significant product life cycle stage and environmental aspect of the toaster respectively.

1.6 Strengths

* It is a systematic, objective and reliable method that includes adequate data to assess the product from an environmental point of view.
* It is a simple method of assessing and prioritizing environmental effects and can save a substantial amount of time and money.
* The database derived from the life cycle inventory can be used to replace data that cannot be collected.
* It is a good method to present as much information as possible about the environmental aspects of products .
* It is a useful tool for weak-point analysis and the identification of potential environmental improvements in the product planning and development stage.

1.7 Weaknesses

* Estimations may be needed to substitute the missing data for compiling the final value for specific impacts when they are not available.
* A reasonable level of background knowledge about the products is needed.
* If quantitative data is lacking, the results are required to be based on an interpretation of qualitative statements.

1.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Use of raw materials, manufacturing, packaging and distribution, use and end of life.

2 AT&T Matrix

2.1 Background

AT&T matrix and target plot, also called Environmentally Responsible Product Assembly Matrix (ERPA), is an environmental assessment method developed by Graedel and Allenby at the US companiy AT&T in 1995. It is a semi-quantitative approach used to provide groundwork for systemic improvements in the environmental performance of a company. The structure of this method is similar to that of the MET matrix, but AT&T matrix and target plot is more systematic. This model provides an environmental impact evaluation tool for engineers when they are generating ideas for innovative products.

2.2 Evaluation method

AT&T model is divided into two parts: matrix and target plot. AT&T matrix evaluates environmental concerns under five life cycle stages while the target plot provides a graphical view of which product area should be improved first. A typical AT&T matrix and target plot are shown in table 2.1 and figure 2.1 respectively.

Table 2.1 AT&T matrix developed by Graedel.

Environmental Concern / Life-cycle stage	Material choice (1)	Energy use (2)	Solid residues (3)	Liquid residues (4)	Gaseous residues (5)
Resource extraction (1)	1.1	1.2	1.3	1.4	1.5
Product manufacture (2)	2.1	2.2	2.3	2.4	2.5
Product delivery (3)	3.1	3.2	3.3	3.4	3.5
Product use (4)	4.1	4.2	4.3	4.4	4.5
Refurbishment, recycling, disposal (5)	5.1	5.2	5.3	5.4	5.5

The five by five matrix is mainly used to evaluate the environmental performance of products for five environmental categories over five life cycle stages. Each cell in AT&T matrix is graded by a rating from 0 (highest negative impact) to 4 (highest positive impact).

2.3 Result interpretation

After an evaluation is made, the overall Environmentally Responsible Product Rating (RERP) can be calculated by summing up all matrix cell values (M_{ij}). R_{ERP} can be computed as follows:

$$R_{ERP} = \sum_{i} \sum_{j} M_{ij}$$

The addition method implies that all life cycle stages and environmental concerns are graded with the same weighting. There are a total of 25 cells in AT&T matrix. Score 4 is the maximum score for each cell, so the maximum R_{ERP} will be 100. As 4 means highest positive environmental load, higher R_{ERP} means the product has a lower environmental impact.

The next step of AT&T model is to present all cell ratings in a target plot. To construct the plots, the values are plotted at a specific angle. The angle spacing for a 25-cell matrix is 360˚ degree divided by 25, and that is 14.4˚. For products with fewer environmental impacts, the dots should be gathered towards the centre.

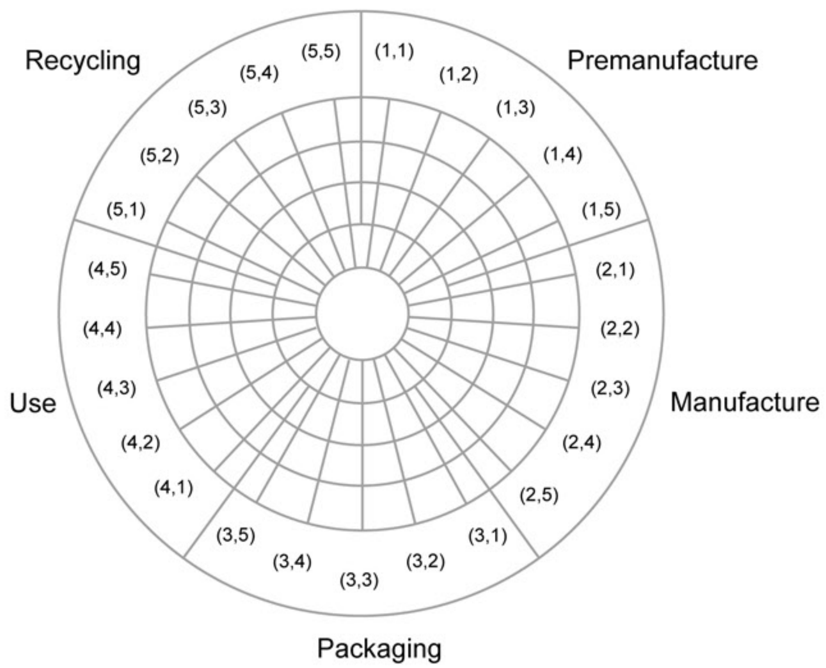


Figure 2.1 AT&T target plot

2.4 Points to be noted

The rating is based on the seriousness and reduction possibilities of impacts. Since the grading task requires experience, a design and manufacturing checklist specific to a product system and scoring guidelines is necessary.

Despite the fact that AT&T matrix and target plot is more systematic than MET matrix, a great number of researchers criticize its scoring system and result quality. According to an experiment conducted among several practitioners, the overall ratings from AT&T matrix vary about 15 percent when some pre-defined scoring lists and questions are supplied. This result shows that environmental product assessment by AT&T matrix and target plot is mainly based on practitioners' own judgment and is quite subjective. There is no reference standard to grade each axis.

2.5 Example

The following example shows how to use AT&T matrix to evaluate the environmental impact from a household mixer cum grinder.

Figure 2.2 The household mixer cum grinder

Table 2.2 AT&T matrix of the household mixer cum grinder

Environmental Concern / Life-cycle stage	Material choice	Energy use	Solid residues	Liquid residues	Gaseous residues	Total score
Resource extraction	2	2	3	3	3	13
Product manufacture	2	3	2	3	3	13
Product delivery	2	3	3	4	2	14
Product use	4	2	4	4	4	17
Refurbishment, recycling, disposal	3	3	3	4	3	16
Total score	13	12	15	18	15	73/100

The result indicates that the energy use is most significant environmental concern. Resource extraction and product manufacture are most significant life cycle stages. The RERP is 73. By plotting the value of 25 cells on the target plot, the AT&T plot is constructed as below.

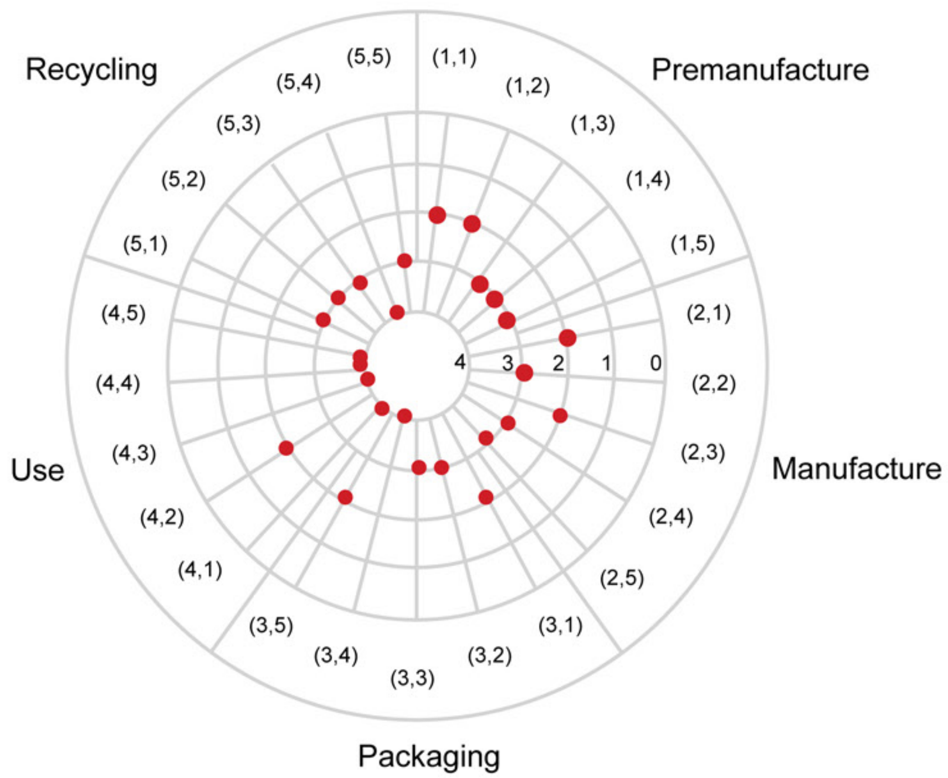


Figure 2.3 AT&T target plot of the household mixer cum grinder

2.6 Strengths

* A clear comparison of different design attributes can be viewed clearly and graphically.
* Target plots for alternative designs of the same product permit quick comparisons of the environmental impacts. The product design team can select among design options more easily, and can consult the checklists and protocols for information on improving individual matrix element ratings.
* It allows the product design team to improve their products, especially in the green product planning and development stage.
* It can be used as an eco-redesign tool to identify potential environmental improvements on special impacts.

2.7 Weaknesses

* It is time consuming and difficult to collect data about score estimation.
* Environmental performance is estimated for the whole product but not for each part or component.
* The scoring system is a subjective process; different users may have different ranking results.

2.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Use of raw materials, manufacturing, packaging and distribution, use and end of life.

3 ABC Analysis

3.1 Background

ABC analysis is an ecological assessment system has been developed by the Institut für ökologische Wirtschaftsforschung (IÖW, Institute for Ecological Economic Research) in Cupertino with Volker Stahlmann. The term ABC is a predefined scale for specific criteria. This method is used to assess the environmental impact of a process or product by integrating a group of specific criteria with the predefined scale.

3.2 Evaluation method

In ABC analysis, the groups of specific criteria are the result of internal discussion and the policies of company. Some generic examples of criteria include: compliance with environmental regulations, social requirements and potential environmental impacts, risk of accidents, life cycle stages, and internal environmental costs. However, all criteria are generally related to hazardous substances in a process or product.

Table 3.1 list of the criteria used in ABC analysis

Product/Process to access	Responsible person		Date
Criteria	A (Problematic)	B (Medium)	C (Harmless)
1.Compliance with environmental regulations			
2.Social requirements			
3.Potential environmental impacts			
· Toxicity			
· Air pollution			
· Water pollution			
4.Risk of accidents			
5.Raw material extraction			
6.Pre-production			
7.Manufacturing and processing			
8.Use phase			
9.End-of-life			
10.Recyclability			
11.International environmental costs			

3.3 Result interpretation

To assess a process or product, criteria in different groups are categorized with a scale A, B, and C. Scale A means the level of environmental impact is problematic. When a specific criterion is categorized under scale A, actions are required. Scale B refers to a medium criteria that needs to be observed and improved. C is a scale that is harmless and no action is required.

3.4 Points to be noted

ABC-Analysis is a rather qualitative orientated evaluation method, which can include argumentative and monetary aspects. It is based on substance flow and energy flow analysis and aims to classify the environmental impacts of diverse factors caused by business activities. The call for action is based on relative assignment of the letters A, B or C, whereby the necessity decreases from A to C. If ecological company objectives are already fixed, then these objectives should be integrated in the evaluation criteria of the ABC-Analysis.

3.5 Example

The following example demonstrates how to use ABC analysis to assess the environmental impact of an LCD TV.

Figure 3.1 the LCD TV

Table 3.2 ABC analysis of the LCD TV

Product/Process to access	Responsible person		Date
LCD TV			
Criteria	A (Problematic)	B (Medium)	C (Harmless)
1.Compliance with environmental regulation		Stricter requirement of implementing measures of TVs is coming	
2.Social requirements		Stricter regulation is demanded	
3.Potential environmental impacts			
· Toxicity		If the backlight tube is broken. The mercury inside the backlight tube will be hazardous to health.	
· Air pollution			Under normal condition, no contributions to air pollution
· Water pollution			Under normal condition, no contributions to water pollution
4.Risk of accidents	The product contains halogenated material for inflammability, toxic gas will be generated with product combustion		
5.Raw material extraction		The raw material extraction is associated with environmental impact by emissions.	
6.Pre-production			Under normal conditions, there are no environmental impacts in terms of health hazards associated with preproduction
7.Manufacturing and processing			Under normal conditions, there are no environmental impacts in terms of health hazards associated with manufacturing and processing
8.Use phase			Under normal conditions, there are no environmental impacts in terms of health hazards associated with using the product
9.End-of-life			Reuse, recycle and recover
10.Recyclability		Partially recyclable	
11.Internal environmental costs		Medium	

According to the table above, there may be some risks of accidents as the product contains halogenated materials. Modifications should be implemented to reduce this problematic area.

3.6 Strengths

* ABC analysis is a simple checklist to help companies identifying potential environmental product improvement.
* The assessment issues for a product in this checklist are wide and can be tailor-made for each user.
* This assessment enables companies to identify potential environmental improvements in a relatively simple manner.

3.7 Weaknesses

* ABC analysis is only concerned about hazardous substances. The eco-efficiency of the product, recycling methods of components, and the assessment of the entire life cycle are not investigated comprehensively.
* Groups of criteria are based on in-house discussions and company policies, different companies or users may have different forms of assessment.
* No standards or guidelines are used when setting the criteria, so results may be subjective.

3.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Use of raw material, manufacturing, use and end of life stages.

4 Recycling Checklist for EC Directive on WEEE

4.1 Background

According to European Council's Directive 2002/96/EC, the design and production of electrical and electronic equipment should consider disassembly and recovery, in particular reuse and recycling of their waste, components and materials. Therefore, recycling is an important part in assessing the environmental impacts of a product.

The method using the recycling checklist described here is specifically for the European Council's Directive on WEEE. This checklist has been developed by the Centre for Sustainable Design in the UK. It is a set of questions that helps users to check the product, mainly on the recycling stage of the product life cycle.

4.2 Evaluation method

Users only need to answer the questions with a tick under column yes (Y), no (N), or data not available (N/A). The questions are concerned on three main areas: the coverage of WEEE for products, concerns on environmental issues, and also the product design objectives and attributes. By using the recycling checklist, nearly all aspects in the WEEE directive can be covered. It can act as a remainder for designers to conform to the stringent European directives. The following table shows a general format of a recycling checklist.

Table 4.1 recycling checklist for the European Council's Directive on WEEE

Questions/Issues	Y	N	N/A	Comments
General: Is the product or end application covered by WEEE Directive?				
A) Does the product or end use of components/subassemblies falls under one of the following applications and not rated greater than 1000V ac or 1500V dc? · Large household appliances · Small household appliances · IT equipment · Telecommunication · Consumer equipment · Lighting equipment · Electrical and electronic tools · Toys, leisure and sports equipment · Medical devices (except implanted and infected products) · Monitoring and control instruments · Automatic dispensers				
B) Does product contain, or potentially contain, the following materials (not exempted under RoHS)? · Lead (except in CRTs) · Mercury · Hexavalent chromium · Cadmium · PCBs · Flame retardants - Polybrominated biphenyls (PBB) - Polybrominated diphenyl ether (PBDE) · Radioactive substances · Asbestos · Beryllium				
C) Do the plastics weigh more than 25 grams? (If yes, material coding is required)				
D) If the product can fall into the class of being separately collected, does the product contain any of the following, as listed in Annex II of WEEE, which will be required to be removed from the product at the end-of-life for separate treatment?				
Environmental Issues/Concerns				
What are the main concerns relating to end-of-life waste from the product, for example: · Hazardous materials · Recycled materials content · Materials recyclability				
Design Objectives/Attributes				
What are the main design objectives/attributes sought? · Longevity, including durability and secondary use · Source reduction (reduced mass) · Low toxicity (avoidance of hazardous substances except in exempted quantities) · Material and/or component recovery · Separability of hazardous components or materials · Disassembly				

4.3 Result interpretation

By using the checklist for the EC Directive on WEEE, the focal product can determine if its product category falls onto the coverage of WEEE directive. Answer "Y" in question A means the product falls into a category of WEEE. The number of Answers "Y" represents how many types of hazardous substance are in the product. Answer "Y" in question C and D represents that specific action required by the WEEE directive is needed.

4.4 Points to be noted

WEEE directive became European law in 2007, and the Electronic and Electrical products in European markets have to meet the requirements of collection, recycling and recovery. The manufacturers have to design or redesign their product regarding above mentioned requirements.

4.5 Example

The following example takes a cordless power drill as a demonstration to show how to assess the recyclability of a product by the recycling checklist for the EC directive on WEEE.

Figure 4.1 the cordless power drill

Table 4.2 WEEE recycling checklist of cordless power drill

Questions/Issues	Y	N	N/A	Comments
General: Is the product or end application covered by WEEE Directive?				
A) Does the product or end use of components/subassemblies falls under one of the following applications and not rated greater than 1000V ac or 1500V dc? · Large household appliances · Small household appliances · IT equipment · Telecommunication · Consumer equipment · Lighting equipment · Electrical and electronic tools · Toys, leisure and sports equipment · Medical devices (except implanted and infected products) · Monitoring and control instruments · Automatic dispensers	✓			
B) Does product contain, or potentially contain, the following materials (not exempted under RoHS)? · Lead (except in CRTs) · Mercury · Hexavalent chromium · Cadmium · PCBs · Flame retardants - Polybrominated biphenyls (PBB) - Polybrominated diphenyl ether (PBDE) · Radioactive substances · Asbestos · Beryllium		✓		
C) Do the plastics weigh more than 25 grams? (If yes, material coding is required)	✓			
D) If the product can fall into the class of being separately collected, does the product contain any of the following, as listed in Annex II of WEEE, which will be required to be removed from the product at the end-of-life for separate treatment?	✓			
Environmental Issues/Concerns				
What are the main concerns relating to end-of-life waste from the product, for example: · Hazardous materials · Recycled materials content · Materials recyclability				Ease of disassembly Materials recyclability
Design Objectives/Attributes				
What are the main design objectives/attributes sought? · Longevity, including durability and secondary use · Source reduction (reduced mass) · Low toxicity (avoidance of hazardous substances except in exempted quantities) · Material and/or component recovery · Separability of hazardous components or materials · Disassembly				Durability Source reduction Disassembly

Coverage of WEEE for product

- According to 2002/96/EC Directive, the drill falls into category 6 (electrical and elec tronic tools).
- The drill does not contain the listed materials.
- The plastics weight is more than 25 grams.

Environmental issues / concerns

In the "end of life", the main environmental concern are ease of disassembly and materials recyclability.

Design objective/ attributes

Considering the operating environment of a power drill, it should be designed with durability. For the ease of use and disassembly, unnecessary parts should be eliminated to reduce the product weight and complexity.

4.6 Strengths

* Easy to be employed as it does not require any special methodological expertise or detail knowledge of WEEE.
* Checklists can be further tailored to specific products and company requirements in any sector, based on the WEEE directive.
* It helps to improve the effectiveness of checking the conformity of WEEE directive.
* The most effective in identifying the specific environmental weak points of a product.

4.7 Weaknesses

* This checklist is only a screening tool for WEEE which cannot be substituted for detailed analysis.
* Additional work maybe required using life cycle assessment (LCA) or other design evaluation methods.
* Most of the ecodesign checklists pose environmentally relevant questions along the product's life cycle, which is a pragmatic approach but involves the risk that interrelations between different life cycle stages may be overlooked.
* This checklist may interfere with creativity because designers may rely on it exclusively to address environmental issues without considering which prompts in the lists are most appropriate for particular products.

4.8 Applicable areas

* Types of product: Electrical and electronic products.
* Product life cycle stages: End of life stage.

5 Ecodesign Checklist Method (ECM)

5.1 Background

The ecodesign checklist method is a qualitative checklist which has been developed by Hans Brezet and Caroline van Hemel in the Netherlands. It is commonly used as a complement to the MET matrix. The main purpose of the ecodesign checklist is to support engineers by reducing the environmental burden of products in product development.

By listing the identified environmental problems and each criteria requirement that have been formulated, weaknesses in different areas, significant characteristics and improvement options for products can be recorded and evaluated. Actually, the ecodesign checklist is a systematic tool that can be used specifically to improve or redesign parts, functions and concepts for the whole product.

5.2 Evaluation method

In order to perform a holistic view of a product, full investigation of the ecodesign checklist method can be divided into three analysis levels: part analysis, function analysis and product analysis. The analysis details of each level are shown in figure 5.1.

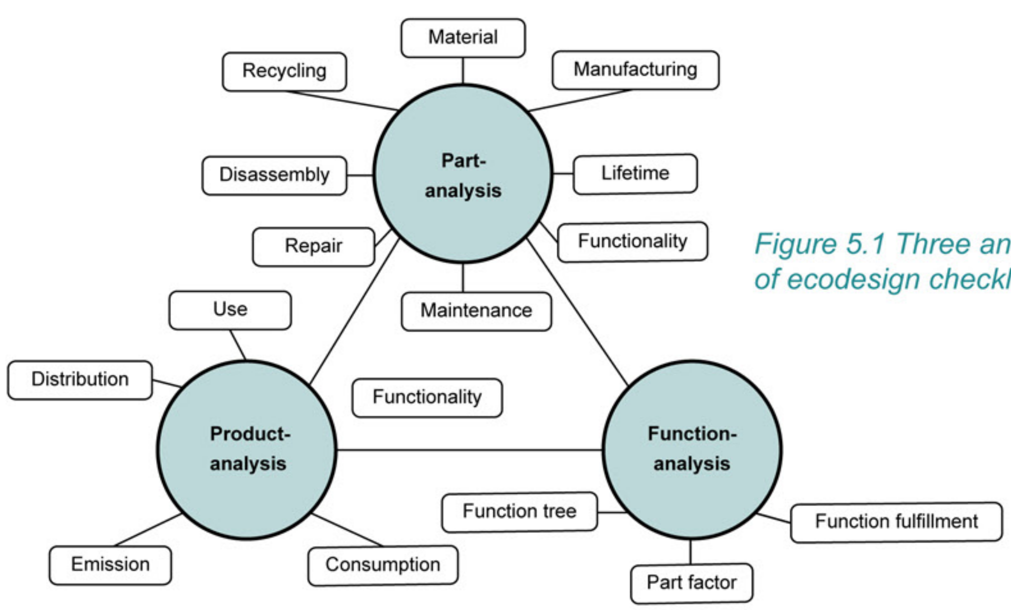


Figure 5.1 Three analysis levels of ecodesign checklist method.

The checklist of every level of analysis starts with a needs analysis. It is a set of questions focusing on the functions of a product. After the need analysis, five sets of questions are used to assess products, corresponding to the five stages across the product life cycle.

To establish the environmental bottlenecks of products, all relevant questions are listed with respect to some supporting data for qualitative environmental analysis. Besides, a set of ecodesign strategies that parallel to those questions are offered in some ecodesign checklista in order to provide some suggestions in the early improvement phase. Table 5.1 shows a sample of a ecodesign checklist with ecodesign strategies.

Table 5.1 Ecodesign checklist with ecodesign strategies.

Ecodesign Checklist	Ecodesign Strategies
Needs analysis	
How does the product actually fulfill social needs? · What are the products main and auxiliary functions? · Does the product fulfill these functions effectively and efficiently? · What user needs does the product currently meet? · Can the product functions be expanded or improved to fulfill users' need · Will this need change over a period of time? · Can we anticipate this through (radical) product innovation?	Ecodesign strategy New concept development · Dematerialization · Shared use of the product · Integration of functions · Functional optimization of product (components)
Life cycle stage 1: Production and supply of materials and components	
What problems can arise in the production and supply of materials and components? · What and how manyt types of plastics and rubber are used? · What and how many, types of additives are used? · What and how many, other types of materials (glass, ceramics etc) are used? · How much, and which type of surface treatments is used? · What is the environmental profile of the components? · How much energy is required to transport the components and materials?	Ecodesign strategy 1 Selection of low-impact materials · Clean material · Renewable materials · Low energy content materials · Recycled materials · Recyclable materials Ecodesign strategy 2 Reduction of material · Reduction in weight · Reduction in (transport) volume
Life cycle stage 2: In-house production	
What problems can arise in the production process in your own company? · How many, and what types of production processes are used (including connections, surface treatments, printing and labeling)? · What and how many types of auxiliary materials are needed? · How high is the energy consumption? · How much waste is generated? · How many products don't meet the required quality norms?	Ecodesign strategy 3 Optimization of production techniques · Alternative production techniques · Fewer production steps · Low/Clean energy consumption · Less production waste · Few/Clean production consumables

Life cycle stage 3: Distribution

What problems arise in the distribution of the product to the customer?

- What kind of transport packaging, bulk packaging and retail packaging are used (volumes, weights, materials, reusability)?
- Which means of transport are used?
- Is transport efficiently organized?

Ecodesign strategy 2
Reduction of material usage

- Reduction in weight
- Reduction in (transport) volume

Ecodesign strategy 4
Optimization of the distribution system

- Less/Clean/Reusable packaging
- Energy-efficient transport mode
- Energy-efficient logistics

Life cycle stage 4: Utilization

What problems arise when using, operating, servicing and repairing the product?

- What and how many typesof energy is required, direct or indirect?
- What and how many typesof consumables are needed?
- What is the technical lifetime?
- How much maintenance and repairs are needed?
- What and how much auxiliary materials and energy are required for operating, servicing and repair?
- Can the product be disassembled by a layman?
- Are parts often requiring replacement detachable?
- What is the aesthetic lifetime of the product?

Ecodesign strategy 5
Reduction of impact in the use stage

- Low energy consumption
- Clean energy source
- Few consumables needed
- Clean consumables
- No wastage of energy or consumables

Ecodesign strategy 6
Optimization of initial lifetime

- Reliability and durability
- Easy maintenance and repair
- Modular product structure
- Classic design
- Strong product-user relation

Life cycle stage 5: Recovery and disposal

What problems can arise in the recovery and disposal of the product?

- How is the product currently disposed of?
- Are components or materials being reused?
- What components could be reused?
- Can the components be disassembled without damage?
- What materials are recyclable?
- Are the materials identifiable?
- Can they be detached quickly?
- Are any incompatible inks, surface treatments or stickers used?
- Are any hazardous components easily detachable?
- Do problems occur while incinerating non-reusable product parts?

Ecodesign strategy 7
Optimization of the end-of-life system

- Reuse of product (components)
- Remanufacturing/Refurbishing
- Recycling of materials
- Safe incineration

5.3 Result interpretation

The EcoDesign checklist is best applied in the concept generation phase, when a clear idea of a product has been developed. It can be also used to analyze existing products. When the checklist is used for a part, the profile indicates to an engineer where to redesign a part. On the other hand, if the checklist is used for a product, the profile helps to obtain product concepts. By answering all questions in the checklist, several improvement options can be generated for significant areas where environmental problems are identified.

5.4 Points to be noted

Before undertaking investigation in the three analysis levels, different tasks have to be prepared. To perform part analysis, the whole product and its components are disassembled into several part groups. Since not every part is necessary for investigation, disassembly of a product into parts can save time to focus on the major part groups. Besides, all relevant data of the part groups for the whole product life cycle has to be available.

Since function analysis can be used to point out any product functions lacking in the ecodesign criteria, a function tree is needed in order to show all possible functions of the product during the investigation. On the other hand, product analysis is used to investigate the entire product system, and an investigator needs to have a good knowledge about on the product concept, functionality and performance.

5.5 Example

The following example demonstrates how to use the ecodesign checklist method to identify the environmental problem of a portable MP3 player.

Figure 5.2 the portable MP3 player

Table 5.2 Ecodesign checklist of the portable MP3 player

Ecodesign Checklist	Ecodesign Strategies
Needs analysis	
How does the product actually fulfill social needs? · What are the products main and auxiliary functions? Entertainment digital media · Does the product fulfill these functions effectively and efficiently? Storing by USB device and playing digital media through earphones. · What user needs does the product currently meet? Provide music entertainment to a user · Can the product functions be expanded or improved to fulfill user needs Yes · Will this need change over a period of time? Yes · Can we anticipate this through (radical) product innovation? Yes	Ecodesign strategy @ New concept development · Dematerialization · Shared use of the product · Integration of functions · Functional optimization of product (components)
Life cycle stage 1: Production and supply of materials and components	
What problems can arise in the production and supply of materials and components? · What and how many types of plastics and rubber are used? 2 types, ABS and PP · What and how many types of additives are used? No · What and how many types of metals are used? 5 types, Copper, aluminum, lithium, silicon and steel · What and how many other types of materials (glass, ceramics etc) are used? 2 types, Liquid ceramic and glass · How much, and which type of surface treatment is used? No · What is the environmental profile of the components? Not available · How much energy is required to transport the components and materials? Euro4 24 tons Truck: 3tkm	Ecodesign strategy 1 Selection of low-impact materials · Clean material · Renewable materials · Low energy content materials · Recycled materials · Recyclable materials Ecodesign strategy 2 Reduction of material usage · Reduction in weight · Reduction in (transport) volume
Life cycle stage 2: In-house production	
What problems can arise in the production process in your own company? · How many, and what types of production processes are used (including connections, surface treatments, printing and labeling)? Four types, Injection molding, sheet metal stamping, folding, vacuum forming · What and how many types of auxiliary materials are needed? · How high is the energy consumption? 0.5kWh · How much waste is generated? 50g Plastic wastes and 104g metal scraps · How many products don't meet the required quality norms? No	Ecodesign strategy 3 Optimization of production techniques · Alternative production techniques · Fewer production steps · Low/Clean energy consumption · Less production waste · Few/Clean production consumables

Ecodesign Checklist	Ecodesign Strategies
Life cycle stage 3: Distribution	
What problems arise in the distribution of the product to the customer? · What kind of transport packaging, bulk packaging and retail packag ing are used (volumes, weights, materials, reusability)? 1000 cm3, 950g, PET and paper for packaging · Which means of transport are used? Euro4 24 tons Truck · Is transport efficiently organized? Yes	Ecodesign strategy 2 Reduction of material usage · Reduction in weight · Reduction in (transport) volume Ecodesign strategy 4 Optimization of the distribution system · Less/Clean/Reusable packaging · Energy-efficient transport mode · Energy-efficient logistics
Life cycle stage 4: Utilization	
What problems arise when using, operating, servicing and repairing the product? · What and how many types of energy is required, direct or indirect? 2 A battery X 1 · What and how many types of consumables are needed? 2A battery · What is the technical lifetime? 5 Years · How much maintenance and repairs are needed? Not required · What and how much auxiliary materials and energy are required for operating, servicing and repair? 2A battery · Can the product be disassembled by a layman? Can not · Are those parts often requiring replacement detachable? Yes · What is the aesthetic lifetime of the product? 5 Years	Ecodesign strategy 5 Reduction of impact in the user stage · Low energy consumption · Clean energy source · Few consumables needed · Clean consumables · No wastage of energy or consumables Ecodesign strategy 6 Optimization of initial lifetime · Reliability and durability · Easy maintenance and repair · Modular product structure · Classic design · Strong product-user relation
Life cycle stage 5: Recovery and disposal	
What problems can arise in the recovery and disposal of the product? · How is the product currently disposed of? Recycling · Are components or materials being reused? Yes · What components could be reused? No · Can the components be disassembled without damage? No · What materials are recyclable? Metal material · Are the materials identifiable? Yes · Can they be detached quickly? No · Are any incompatible inks, surface treatment or stickers used? No · Are any hazardous components easily detachable? No · Do problems occur while incinerating non-reusable product parts? Yes	Ecodesign strategy 7 Optimization of the end-of-life system · Reuse of product (components) · Remanufacturing/Refurbishing · Recycling of materials · Safe incineration

5.6 Strengths

* As the comprehensive checklists can be used for three analysis levels, practitioners can effectively identify the weak points and potential environmental improvements of different functions, parts or products.
* It is useful to delineate design concepts in the product planning and development stage by assessing those environmental aspects involved in different life cycle stages.
* It is applicable to most types of products and allows comparison between new concepts and the reference product
* The result is easy to understand with respect to ecodesign and eco-redesign aspects.

5.7 Weaknesses

* The assessment questions are generated independent so that no connections can be found between the life cycle stages or the three analysis levels.
* Not all environmental aspects posed in the questions are related to most types of products. It seems not valuable and time consuming for practitioners to be concerned about those questions.
* The assessment quality depends on the data availability. If the data is insufficient, estimations and subjectivity will be involved during the assessment. As a result, the assessment quality is totally affected.

5.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Use of raw materials, manufacturing, packaging and distribution, use and end of life.

6 Eco-estimator

6.1 Background

Eco-estimator is a checklist concerned with electrical and electronic products. It is a two-page questionnaire that has been developed by Philips. Eco-estimator is a part of the ecodesign method in Philips. In fact, this checklist is an independent assessment method used to calculate the total environmental value using numerous questions and weighting factors on the product.

6.2 Evaluation method

Table 6.1 is a general format of eco-estimator. The relations between each question are shown in the calculation steps. In the checklist, questions are divided into four sections: product life, energy and materials, recyclability and hazardous waste. Technical product life is used at the beginning in eco-estimator since most functional products will have second-hand users. The total number of years for whole product to be used should be clarified. As energy consumption and packaging are critical for electrical products and electronic appliances, the quantities used for different types of product are important in section B (energy and materials).

Table 6.1 Worksheet for eco-estimator.

Product Name:				
Responsible Person:		Date:		
Question	**Equation**	**Value**	**Unit**	**Remarks**
Product Life				
1a) How many years is this type of product used for?			Years	
1b) Does easy repair increase the number of years of use?			Years	Add on the number of years
1c) Does upgradeability increase the number of years of use?			Years	Add on the number of years
Total product life (A)	1a+1b+1c		Years	
Energy and Materials				
2a) How many watts of electricity does it use per hour in normal mode? (If energy efficiency decreases as product ages, average efficiency over product life is used)			W	
2b) How many hours is it used per year in the normal mode? (Hours per day multiplied by days per year)			h/y	
2c) How many kilowatt hours per year in the normal mode?	2ax2b/1000		kw˙h/y	
2d) How many watts of electricity does it use per hour in the secondary mode? (Same as 2a)			W	
2e) How many hours used per year in the secondary mode?			h/y	
2f) How many kilowatt hours per year in the secondary mode?	2dx2e/1000		kw˙h/y	
2g) What is the total number of kilowatt hours per year?	2c+2f		kw˙h/y	
2h) What is the total quantity of electricity per product life time?	Ax2gx0.7		Points	
2i) How much does the packaging weigh in kilograms?			Kg	
2j) How much does the product weigh in kilograms?			Kg	
2k) How much do the product and the packaging weigh combined?	2i+2j		Kg	
2l) Is the weight of the packaging compared to the weight of the product more than 15%? (Packaging % = 2i/2k)			Points	Yes = 2 No = 0.5
2m) Does the packaging use less than 90% recycled paper? (including box, paper buffers and any other paper in packaging)			Points	Yes = 2 No = 0.5
2n) Packaging factor	2l + 2m		Points	
2o) Packaging points	2ix2n		Points	
2p) Transit factor. Is the product in transit more than 20% of its time? (For intensively transported products in cars, trains etc. or portable electronic diaries or watches)			Points	Yes = 40 No = 0
2q) Does product use more than 20% recycled metal or recycled plastic? (Only consider components with 50% or more of the total product weight)			Points	Yes = 2 No = 5
2r) Product material energy factor?	2p+2q		Points	
2s) Material-related product points	2rx2j		Points	
Subtotal B	2h+2o+2s		Points	
Recyclability				
3a) Are the housing and other large parts easily separated into mono-material pieces? (If final plastics are to be mixed, plastic compatibility is regarded)				Yes = 0 Somewhat = 1 No = 2
3b) Are metal parts easily separable from each other? (Can parts heavier than 100 grams be separated into mono-material fractions?)				Yes = 0 Somewhat = 1 No = 2
3c) Are non-recyclable elements used with plastic: non-recyclable flame retardants, paper stickers on plastic parts, or non-recyclable adhesive? (Consider parts heavier than 100 grams)				Yes = 1 No = 0
3d) Are thermoset plastics used for parts heavier than 100 grams? (Thermoset plastics can only be used as 30% filler in new plastic)				Yes = 1 No = 0
3e) Are plastic parts heavier than 50 grams labeled to identify the plastic type?				Yes = 1 No = 0
3f) Recyclability total	3a+3b+3c +3d+3e		Points	
Subtotal C	3fx2j		Points	
Hazardous waste				
4a) Product contains one or more banned substances according to law and company policy.				Yes = 400 No = 0
4b) The product uses batteries. (if not, go to 4c) i. It only has small batteries for emergency back-up power. ii. It uses rechargeable batteries which are recharged inside the product. iii. It uses rechargeable batteries which are recharged outside the product. iv. It uses either rechargeable or non-rechargeable batteries. v. It cannot use rechargeable batteries. vi. Battery disposal text or symbol is printed/embossed on the product. vii. Battery disposal text or symbol is not printed/embossed on the product.				i. No = 0 Yes = 15 ii. Yes = 30 iii. Yes = 40 iv. Yes = 120 v. Yes = 200 vi. Yes = 0 vii. Yes = 100
4c) Is polyvinyl chloride (PVC) used, including cable or packaging?				Yes = 40 No = 0
4d) Are the printed circuit boards and electronics on the product easily removable modules? (Can the electronics be simply and quickly removed from the product?				Yes = 40 No = 0
Hazardous waste total (Subtotal D):	4a+4b+4c +4d		Points	
Eco-estimator total	B+C+D		Points	
Eco-estimator per Year	(B+C+D)/A		Points / Year	

6.3 Result interpretation

After the total environmental value is summed up, eco-estimator is then used as a quick evaluation to compare environmental impacts of new product with a reference product. A product with lower total environmental value has a better environmental performance.

6.4 Points to be noted

To analyze products accurately, the product should be assembled before answering questions in section C (recyclability). Moreover, questions in section D (hazardous waste) will be different when eco-estimator is applied in different companies. One reason is banned substances in different companies will be different. Generally, at least legal substances are to be mentioned in this part. After filling in all values in the four sections, a total eco-estimator value for a specific product can be calculated.

6.5 Example

The following example shows how to use Eco-estimator to calculate the environmental value of complex set top box.

Figure 6.1 The complex set top box

Table 6.2 Eco-estimator worksheet of the complex set top box

Product Name:Complex set top box				
Responsible Person:	Date:20 / 7 / 2011			
Question	Equation	Value	Unit	Remarks
Product Life				
1a) How many years is this type of product used for?		5	Years	
1b) Does easy repair increase the number of years of use?		3	Years	Add on the number of years
1c) Does upgradeability increase the number of years of use?		2	Years	Add on the number of years
Total product life (A)	1a+1b+1c	10	Years	
Energy and Materials				

2a) How many watts of electricity does it use per hour in normal mode? (If energy efficiency decreases as product ages, average efficiency over product life is used)		20	W	
2b) How many hours is it used per year in the normal mode? (Hours per day multiplied by days per year)		1460	h/y	
2c) How many kilowatt hours per year in the normal mode?	2ax2b/1000	29.2	kw˙h/y	
2d) How many watts of electricity does it use per hour in the secondary mode? (Same as 2a)		8	W	
2e) How many hours used per year in the secondary mode?		7300	h/y	
2f) How many kilowatt hours per year in the secondary mode?	2dx2e/1000	58.4	kw˙h/y	
2g) What is the total number of kilowatt hours per year?	2c+2f	87.6	kw˙h/y	
2h) What is the total quantity of electricity per product life time?	Ax2gx0.7	613.2	Points	
2i) How much does the packaging weigh in kilograms?		0.568	Kg	
2j) How much does the product weigh in kilograms?		6.314	Kg	
2k) How much do the product and the packaging weigh combined?	2i+2j	6.882	Kg	
2l) Is the weight of the packaging compared to the weight of the product more than 15%? (Packaging % = 2i/2k)		No	Points	Yes = 2 No = 0.5
2m) Does the packaging use less than 90% recycled paper? (including box, paper buffers and any other paper in packaging)		No	Points	Yes = 2 No = 0.5
2n) Packaging factor	2l + 2m	1	Points	
2o) Packaging points	2ix2n	0.568	Points	
2p) Transit factor. Is the product in transit more than 20% of its time? (For intensively transported products in cars, trains etc. or portable electronic diaries or watches)		Yes	Points	Yes = 40 No = 0
2q) Does product use more than 20% recycled metal or recycled plastic? (Only consider components with 50% or more of the total product weight)		No	Points	Yes = 2 No = 5
2r) Product material energy factor?	2p+2q	45	Points	
2s) Material-related product points	2rx2j	284	Points	
Subtotal B	2h+2o+2s	897.768	Points	
Recyclability				
3a) Are the housing and other large parts easily separated into mono-material pieces? (If final plastics are to be mixed, plastic compatibility is regarded)		Yes		Yes = 0 Somewhat = 1 No = 2
3b) Are metal parts easily separable from each other? (Can parts heavier than 100 grams be separated into mono-material fractions?)		Some what		Yes = 0 Somewhat = 1 No = 2
3c) Are non-recyclable elements used with plastic: non-recyclable flame retardants, paper stickers on plastic parts, or non-recyclable adhesive? (Consider parts heavier than 100 grams)		No		Yes = 1 No = 0
3d) Are thermoset plastics used for parts heavier than 100 grams? (Thermoset plastics can only be used as 30% filler in new plastic)		Yes		Yes = 1 No = 0
3e) Are plastic parts heavier than 50 grams labeled to identify the plastic type?		Yes		Yes = 0 No = 1
3f) Recyclability total	3a+3b+3c +3d+3e	3	Points	
Subtotal C	3fx2j	18.942	Points	

Hazardous waste				
4a) Product contains one or more banned substances according to law and company policy.		No		Yes = 400 No = 0
4b) The product uses batteries. (if not, go to 4c) i. It only has small batteries for emergency back-up power. ii. It uses rechargeable batteries which are recharged inside the product. iii. It uses rechargeable batteries which are recharged outside the product. iv. It uses either rechargeable or non-rechargeable batteries. v. It cannot use rechargeable batteries. vi. Battery disposal text or symbol is printed/embossed on the product. vii. Battery disposal text or symbol is not printed/embossed on the product.		No		i. No = 0 Yes = 15 ii. Yes = 30 iii. Yes = 40 iv. Yes = 120 v. Yes = 200 vi. Yes = 0 vii. Yes = 100
4c) Is polyvinyl chloride (PVC) used, including cable or packaging?		Yes		Yes = 40 No = 0
4d) Are the printed circuit boards and electronics on the product easily removable modules? (Can the electronics be simply and quickly removed from the product?		No		Yes = 40 No = 0
Hazardous waste total (Subtotal D):	4a+4b+4c+4d	40	Points	
Eco-estimator total	B+C+D	956.71	Points	
Eco-estimator per Year	(B+C+D)/A	95.671	Points / Year	

After summing up the scores of energy and materials, recyclability and hazardous waste (B+C+D), the environmental value per year is obtained by dividing by the product life years (A). The total environmental value of the vacuum cleaner is 956.71. The environmental value per year is 95.671.

6.6 Strengths

* The users of the checklist do not have to carry out the actual assessment, they only have to answer questions and calculate data. It is easy to conduct even though the user does not have background knowledge on environmental product assessment.
* It is an objective assessment tool since judgments are already incorporated in the weighing factors of the eco-estimator.
* The data collection process is shortened as the user does not need to collect a huge amount of data for setting assessing criteria.

6.7 Weaknesses

* A reference product must be provided for comparison, otherwise, the eco-estimator value is meaningless.
* Collecting the necessary information to answer the eco-estimator questions takes up about 75% of the total workload.
* All questions must be answered carefully and precisely as a minor difference will greatly affect the result accuracy.

6.8 Applicable areas

* Types of product: Products that involve the use of energy.
* Product life cycle stages: Use of raw material, manufacturing, distribution, use and end of life stages.

7 Philips Fast Five Checklist

7.1 Background

Philips fast five checklist is a purely qualitative approach that has been developed by Philips. It is a quick check method used for assessing initial concepts of a new product with a reference product during the product planning and development stage.

7.2 Evaluation method

To complete a fast five checklist, users need to answer questions with yes/no entries in five categories; they are i) energy, ii) recyclability, iii) hazardous waste content, iv) durability, reparability and preciousness, v) alternative ways to provide service. A general format of Philips fast five checklist is shown in table 7.1.

Table 7.1. Checklist for Philips fast five method

Product/Project:			
Person in charge:			
Date:			
Category	**Question**	**Yes**	**No**
Energy	Does the proposed design require less energy than the reference product? (consider manufacturing, transportation, product use)		
Recyclability	Is the proposed product more recyclable than the reference product? · Separation of large components/assemblies into mono-material subassemblies · Amount of actually recyclable materials in the product		
Hazardous waste content	Does the product design contain and/or produce less chemical waste than the reference product design? · Any restricted materials such as halogenated flame retardants, cadmium pigments, or ozone depleting chemicals (ODSC)		
Durability, reparability and preciousness	Does the proposed design have better durability, reparability or affection level than the reference product? · New design last longer and easier to upgrade? · Will the precious quality of the new product make the user/owner keep the product longer?		
Alternative ways to provide service	Are there ways to provide service that produces a lower ecological load? · Techniques that require lower energy/material but provide the same service or quality.		

7.3 Result interpretation

When practitioners complete the checklist by filling “yes” or “no”, interpretation about the assessed product can be concluded based on table 7.2. The number of time for answering “yes” is counted according to the overall results of each category. When “yes” appeared three times, the product is considered to be an interesting alternative but still has room for improvement. If the answer is “yes” only one time, it’s not necessary to upgrade the reference product. Therefore, the product would be better if more “yes” responses appear.

Table 7.2 Result interpretations of Philips fast five checklist.

No. of times answering “Yes”	Result interpretation
0	Where is your ‘green’ feeling?
1	Not necessary to upgrade the reference.
2	Pleases reconsider the proposed concept.
3	Interesting alternative, but where still to improve.
4	Probably a viable choice.
5	An excellent alternative.

7.4 Points to be noted

Normally, Philips fast five checklist is suitable for the brainstorming of new product concepts on the strategic level since only a few questions are included. Nonetheless, the result accuracy is highly dependent on the level of thorough investigation.

7.5 Example

The following example shows how to use Philip's fast five checklist to assess a newly designed simple set top box with a reference model.

Figure 7.1the new simple set top box (L) and Reference model of simple set top box(R)

Table 7.3 Philips fast five checklist of simple set top box.

Product/Project:Simple set top box			
Person in charge:			
Date:			
Category	Question	Yes	No
Energy	Does the proposed design require less energy than the reference product? (consider manufacturing, transportation, product use)	✓	
Recyclability	Is the proposed product more recyclable than the reference product? · Separation of large components/assemblies into mono-material subassemblies · Amount of actually recyclable materials in the product	✓	
Hazardous waste content	Does the product design contain and/or produce less chemical waste than the reference product design? · Any restricted materials such as halogenated flame retardants, cadmium pigments, or ozone depleting chemicals (ODSC)	✓	
Durability, reparability and preciousness	Does the proposed design have better durability, reparability or affection level than the reference product? · New design last longer and easier to upgrade? · Will the precious quality of the new product make the user/owner keep the product longer?	✓	
Alternative ways to provide service	Are there ways to provide service that produces a lower ecological load? · Techniques that require lower energy/material but provide the same service or quality.	✓	

There are totally 5 times in answering "yes". The new design of a simple set top box can be interpreted as an "excellent alternative".

7.6 Strengths

* It is suitable for a first assessment of new product concepts in managerial brainstorming or as a quick check during the product planning and development stage.
* It does not require a high level of knowledge and special methodological expertise.
* It can help to minimize the production cost due to re-production and modification of a problematic product. Since the assessment is done at an early stage, possible problems can be found and solved before the product goes to the production line.

7.7 Weaknesses

* The result accuracy is highly dependent on the level of thorough investigation.
* Yes/no answers cannot tell the degree of difference, it can only indicate if the new product is better or worse than the old one.
* This method is too simple with only five questions for checking, so no detailed results can be concluded from the answer.

7.8 Applicable areas

* Types of product: Products that involve the use of energy.
* Product life cycle stages: Use and end of life stage.

8 Sony's Green Product Check Sheet and Product Profile

8.1 Background

Sony's green check sheet and product profile were developed by Sony's Japan personnel in 1994. It is a semi-quantitative method which is widely used to capture different product aspects in the product planning and development stage for environmental improvement. Those selected aspects are based on the environmental load items found in entire product life cycle. Sony's green product check sheet and product profile provide a clear environmental design direction and product progress evaluation in achieving environmental goals.

8.2 Evaluation method

This method is divided into two main parts: green product check sheet and product profile. Green product check sheet evaluates environmental concerns during product planning and development while the product profile provides a graphical view of the most actionable improvement aspects. Generally, Sony uses this method to compare new or proposed designs with existing models or reference products.

Table 8.1 shows some pre-defined items that needed to be evaluated in the green product check sheet. According to the degree of goal achievement, scores from different items are assigned values from 0 to 10 points. When the new or proposed design meets Sony's own standard with lower environmental impact, the scored points will be higher.

Table 8.1 Green product check sheet from Sony's Japan.

Model:	Date:	Evaluated by:		
	Item	Evaluation method	Score	Remarks
Materials with high environmental impact	Observes relevant national regulations:	5 points		Refer to Sony's specified environmental substances
	Observes higher industry standards:	7 points		
	Observes higher Sony standards:	8 points		
	High-impact materials eliminated:	10 points		
Disassembly time	Reduction in time to dismantle product - New model, T_{new} …(min) - Reference model, T_{ref} …(min)	$\left[1-\left(\frac{T_{new}}{T_{ref}}\right)\right]\times 100\%$ =__%		60% reduction is 10 points
Labeling of materials types	No labeling:	0 points		
	Observes product assessment standards:	5 points		
	All material labeled:	10 points		
Recyclability	Recyclability improvement ratio, where recyclability is the percentage of materials, by weight, for which recycling is feasible. - New model recyclability, R_{new} … (%) - Reference model, R_{ref} …(%)	$\left(\frac{R_{new}-R_{ref}}{100\%-R_{ref}}\right)\times 100\%$ =__%		60% improvement is 10 points
Recycled resource usage ratio	Recycled glass usage as % of total glass weight:	Recycle/total =__%		50% is 10 points, 0% is 0 points
	Recycled plastic usage as % of total plastic weight:	Recycle/total =__%		
	Recycled paper usage as % of total paper weight:	Recycle/total =__%		100% is 10 points

Material resource conservation	Product weight reduction ratio - New model, W_{new} ……(__g) - Reference model, W_{ref}……(__g)	$\left[1-\left(\frac{W_{new}}{W_{ref}}\right)\right]\times100\%$ =__%		50% is 10 points, 0% is 0 points
	Product volume reduction ratio - New model, V_{new}… (__cm3) - Reference model, V_{ref}…(__cm3)	$\left[1-\left(\frac{V_{new}}{V_{ref}}\right)\right]\times100\%$ =__%		
Product life	Initial failure rate	___%		<0.3% is 10 points, ≧3.0% is 0 points
	Annual failure rate standards:	___%		<0.5% is 10 points, ≧5.0% is 0 points
	Warranty period	___yrs		
Energy conservation	Energy consumption with main power off:	___Watts		0W is 10 points, ≧2W is 0 points
	Energy consumption in standby mode:	___Watts		
	Energy consumption during use - New model, E_{new} …(__W) - Reference model, E_{ref} …(__W)	$\left[1-\left(\frac{E_{new}}{E_{ref}}\right)\right]\times100\%$ =__%		60% reduction is 10 points
Packaging	Polystyrene foam usage reduction - New model, F_{new} ……(__g) - Reference model, F_{ref} …(__g)	$\left[1-\left(\frac{F_{new}}{F_{ref}}\right)\right]\times100\%$ =__%		60% reduction is 10 points
	Packaging weight reduction ratio - New model, W_{pack}^{new} … (__g) - Reference model, W_{pack}^{ref}…(__g)	$\left[1-\left(\frac{W_{pack}^{new}}{W_{pack}^{ref}}\right)\right]\times100\%$ =__%		
	Recycled resource usage as % of total packaging weight:	Recycle/total =__%		

8.3 Result interpretation

After completing the sheet, scores will be plotted in the product profile. Each axis of product profile represents one item in the green product check sheet items. The centre point of the profile indicates a score of 0 and the outer contour is a full score of 10. Figure 8.1 shows the product profile developed by Sony in Japan. To compare design ideas, both new or proposed ideas and reference ideas are plotted in the same profile.
For displaying the results of the check sheet item above, a radar chart has been adapted by Sony. It is commonly used in benchmarking applications with multiple dimensions of performance.

Checklists

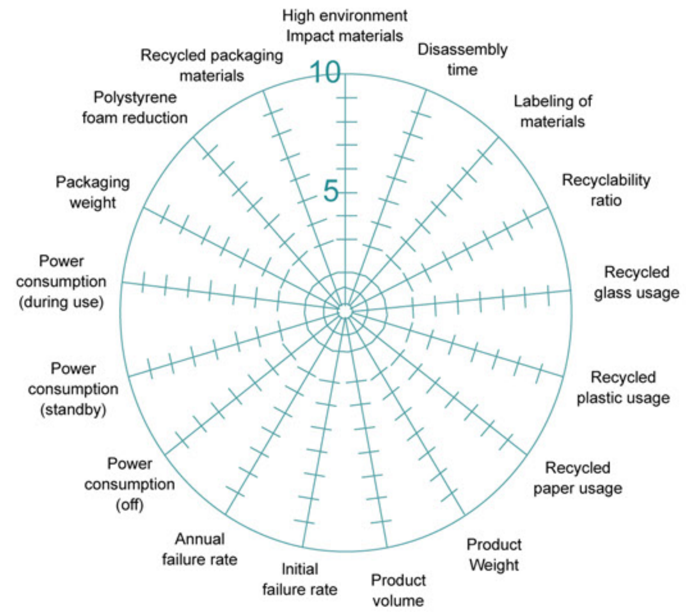


Figure 8.1 Product profile using item scores from green product check sheet.

8.4 Points to be noted

Items used in this method are specifically defined within each company. Practitioners need to retrieve some related data from their company in order to set the green product check sheet for a particular product.

8.5 Example

The following example demonstrates how to compare the environmental performance of a new heart rate monitor with the reference model above. The new model is at the conceptual design level and the table shows the main modification.

Figure 8.2 The reference heart rate monitor

Table 8.2 The bill of materials (BOM) of the original design and the new design

Phase	Modifications	Original Design (kg)	New design (Weight per unit (kg))
Material	Fabric Glove	N/A	0.0158
Material	Glove Contact	N/A	0.00612
Material	Watch Base Latch	N/A	0.002
Material	Watch Wrist Strap DBLU PMS654C (short + long)	0.0158	0
Material	PLAS BIKE MOUNT BLK PU-85-95/H	0.031	0
Material	Ferrite Bar D3XL38mm	0.005	0
Material	Chest Belt	0.0698	0
Manufacturing	Relevant process reduced	Approx. 0.0035 MJ Per Product	Approx. 0.00295 MJ Per Product
Packaging, Transportation & Distribution	Manual (Weight reduced by 10%)	0.0997	0.08973
Packaging, Transportation & Distribution	Gift box (50mmx30mm x80mm)	0.035	0.0245
Packaging, Transportation & Distribution	Box insert (49.7mmx29.7mmx 79.7mm)	0.0576	0.04032
Packaging, Transportation & Distribution	Packaging volume and transportation quantity	Approx. 8 pieces per master carton	Approx. 16 pieces per master carton,30.4% weight reduction
Use & Maintenance	Lifetime of the HRM	3 years	3 years
Use & Maintenance	Lithium Battery	5 + 5 pieces	5 pieces
End of Life	Based on a WEEE recovery target model (Category 4)	Proportional to the other phases	Proportional to the other phases

Table 8.3 Green product check sheet of heart rate monitor's new design.

Model			
	Item	Score	Remarks
Materials with high environmental impact	Observes relevant national regulations:	5	Refer to Sony's specified environmental substances
	Observes higher industry standards:		
	Observes higher Sony standards:		
	High-impact materials eliminated:		
Disassembly time	Reduction in time to dismantle product	8	60% reduction is 10 points
Labeling of materials types	No labeling:		
	Observes product assessment standards:	5	
	All material labeled:		
Recyclability	Recyclability improvement ratio, where recyclability is the percentage of materials, by weight, for which recycling is feasible	6	60% improve-ment is 10 points
Recycled resource usage ratio	Recycled glass usage as % of total glass weight:	2	50% is 10 points, 0% is 0 points
	Recycled plastic usage as % of total plastic weight:	6	
	Recycled paper usage as % of total paper weight:	8	100% is 10 points
Material resource conservation	Product weight reduction ratio	8	50% is 10 points, 0% is 0 points
	Product volume reduction ratio	4	
Product life	Initial failure rate	5	<0.3% is 10 points, ≧3.0% is 0 points
	Annual failure rate	10	<0.5% is 10 points, ≧5.0% is 0 points
	Warranty period	1	

Energy conservation	Energy consumption with main power off:	6	0W is 10 points, ≧2W is 0 points
	Energy consumption in standby mode:	6	
	Energy consumption during use	9.5	60% reduction is 10 points
Packaging	Polystyrene foam usage reduction	10	60% reduction is 10 points
	Packaging weight reduction ratio	8	
	Recycled resource usage as % of total packaging weight:	7	

The radar map can then be drawn according to the result in the table.

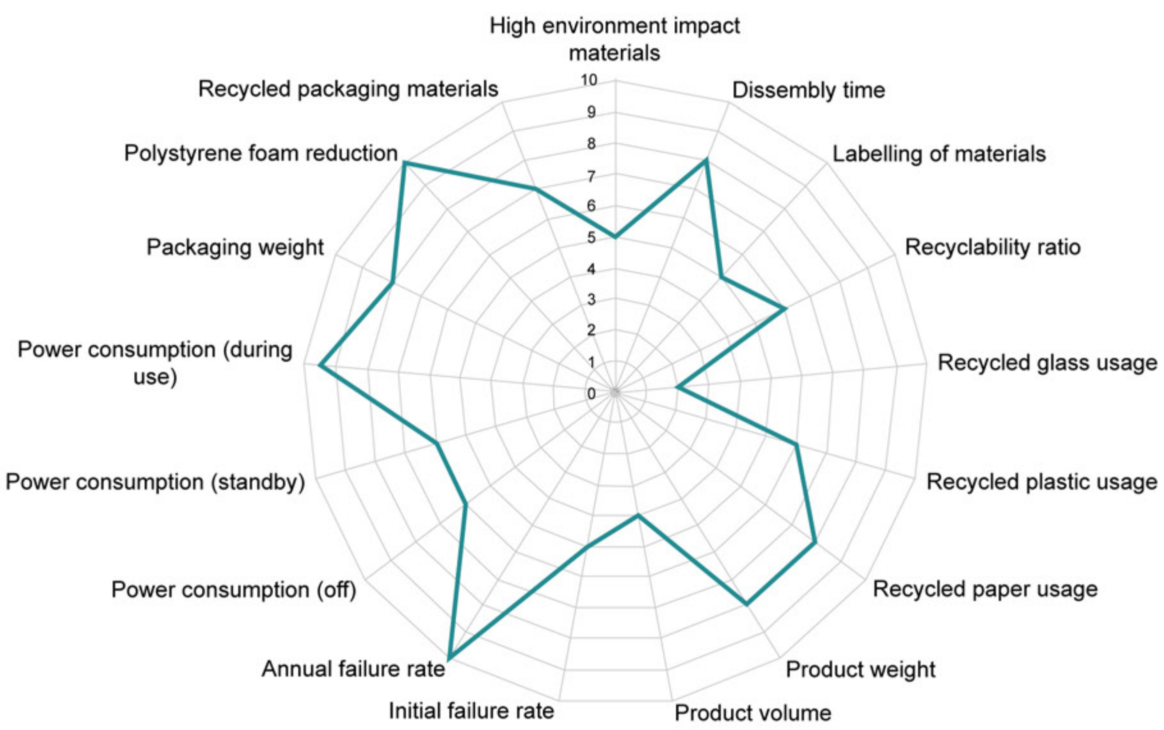


Figure 8.3 The radar map of the heart rate monitor

8.6 Strengths

* Each item and its weighting in the green design check sheet can be flexibly modified in order to fit different types and characteristics of products.
* Clear guidelines have been set for the scoring system.
* The product profile clearly shows the difference between products.
* The numerical results can be visualized by plotting the product profile, so it may be easier to communicate between departments.

8.7 Weaknesses

* The subjective evaluations are insufficient to improve environmental product performance, even they are ascertained.
* A reference product must be provided for comparison, so new product concepts can not be evaluated by this method.
* Several assumptions are required which may affect the assessment results.

8.8 Applicable areas

* Types of product: Products that involve the use of energy.
* Product life cycle stages: Use of raw material, packaging and distribution, use and end of life stages.

9 Eco-compass

9.1 Background

The Eco-compass spider web diagram was developed by David Russell with his colleagues in Dow, a diversified chemical company, in Europe. It is a part of the company's Eco-Innovation process. Since results from the traditional life cycle assessment are too complex and detailed for making final decisions, Eco-compass was developed as a holistic approach for product environmental aspects in view of certain selected criteria in order to overcome the weaknesses of traditional life cycle assessment.

9.2 Evaluation method

The main purpose of this model is to compare existing or new ideas with a reference product or activity by means of weighting the inputs and outputs for some important environmental aspects. It is also used to condense environmental data in a simpler way which summarizes strategic issues, trade-offs and improvement opportunities for products and activities.

Figure 9.1 shows a typical format of Eco-compass with six poles (dimensions). The six dimensions in Eco-compass encompass all aspects of ecological and resources security. In reality, all dimensions are not independent. They overlap each other to perform actual performance of the assessed products or activities. Besides, trade-offs can be highlighted between different dimensions after completing Eco-compass.

Spider-web Diagrams

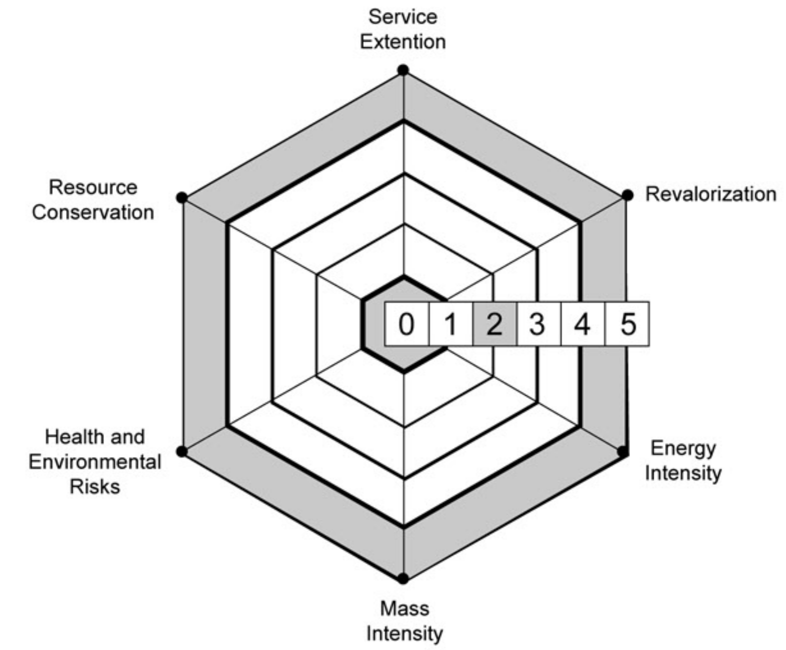


Figure 9.1 Typical format of Eco-compass

9.3 Result interpretation

A scoring system of points 0 to 5 is used for rating different aspects. As Eco-compass cannot used to assess single product, a general point "2" will be used for a reference product or activity in each dimension. Figure 9.2 is the evaluation method of scoring ideas against a reference product. The scoring system for each dimension depends on the percentage increase or decrease in performance. Thus, higher rating means the compared option has a better performance than the reference one. On the other hand, if the contour of the compared option gets closer to the outer limit of the hexagon, the compared option is better. Since it is a logarithmic scale, the aggregate score can be calculated referring to the individual scores for specific stages of the life cycle.

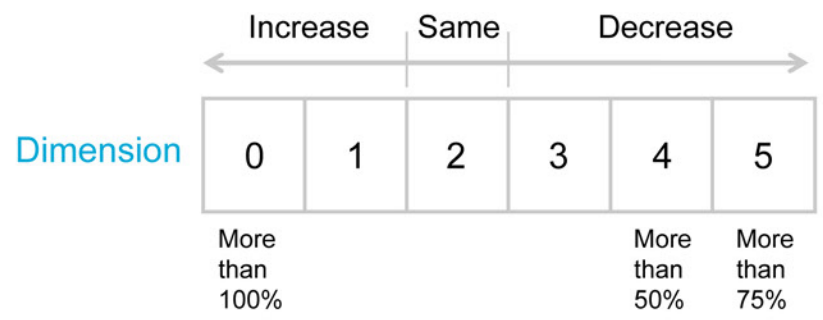


Figure 9.2 Evaluation grid to compare ideas against reference product.

9.4 Points to be noted

Before using Eco-compass for assessment, data for products and activities are gathered on the basis of a functional unit or service unit. The unit is defined according to “customer or consumer phase of the life cycle and is a measure of the delivery of a service to a customer”. Different aspects are scored with respect to six dimensions: service extension, revalorization (remanufacturing, reuse and recycling), energy intensity, mass intensity, health and environmental risks, and resource conservation.

9.5 Example

The following example demonstrates how to compare the environmental performance of a new washing machine with a reference model.

Figure 9.3 the reference model of washing machine (L) and the new model of washing machine (R)

To compare the environmental performances of two washing machines, the Eco-compass is designed to include:

Spider-web Diagrams

Table 9.1 Items included in the eco-compass

Items	Reference product	New product	Change in %
Mass intensity: (Quantity of material per unit /service)	65 kg	75 kg	Worse 15.3%
Energy intensity: (Energy consumption / kg)	0.9 KWh / kg	0.7 KWh / kg	Better 22%
Extending service and function: (Washing efficiency index)	1.04 of Iw	1.06 of Iw	Better 2%
Health and environmental risks: (Quantity of hazardous substances emitted to air soil and water)	None	None	The same
Resource conservation: (Water consump-tion)	45 liters / cycle	40 liters / cycle	Better 11%
Reuse & revalorization of waste (Reuse and recycling content)	75%	80%	Better 6%

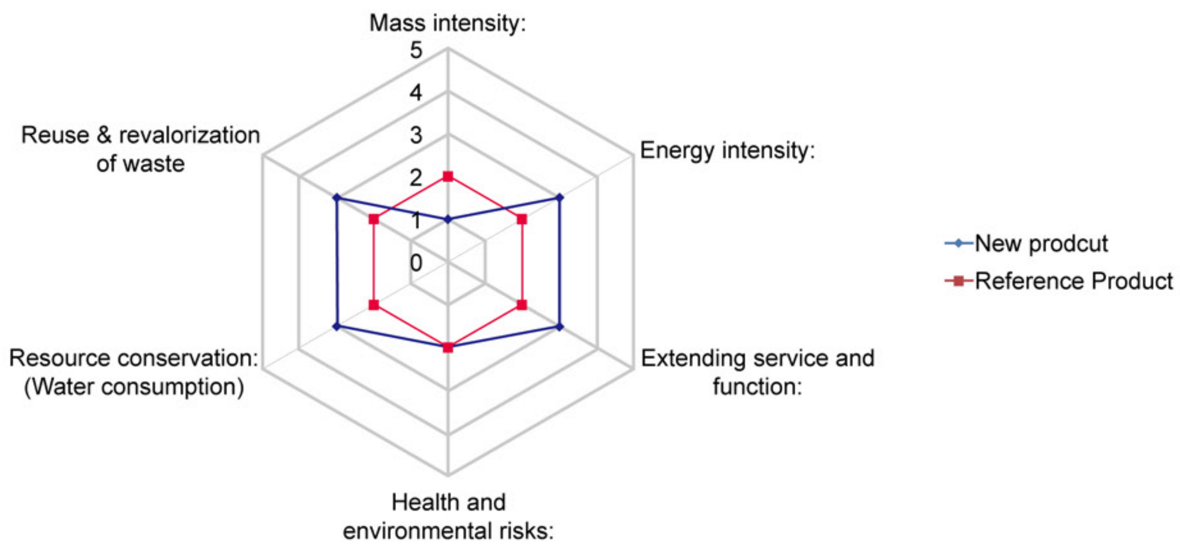


Figure 9.4 Eco-compass of the reference model and the new model

The new washing machine is better than the reference washing machine as the contour of new design gets to the outer limits of the hexagon.

9.6 Strengths

* Eco-compass is more logarithmic a linear. Practitioners can grade different aspects with a guiding percentage instead of their own judgments.
* Eco-compass can highlight the major differences between the assessed concept and the reference product immediately.
* This method can be reliably applied to a variety of business circumstances.
* It allows users to adjust the levels of detail very easily if changes are applied.

9.7 Weaknesses

* Eco-compass can only apply to comparisons between similar products but not individual assessments.
* There are very few criteria involved in this tool, so it may not be applicable to most types of products.
* Only suitable for internal use.

9.8 Applicable areas

* Types of product: Developing products based on existing model.
* Product life cycle stages: Use of raw material and use stages.

10 E-concept Spiderweb Diagram

10.1 Background

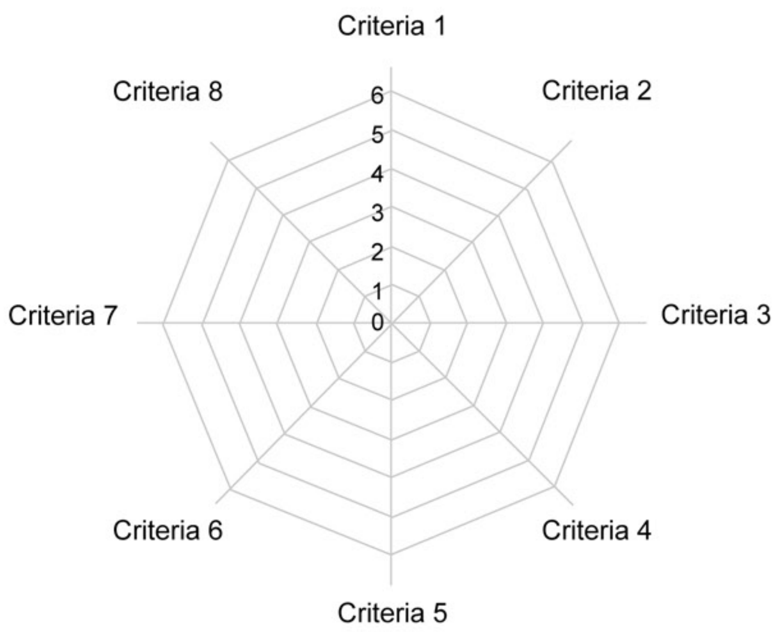
This spiderweb diagram has been developed by E-concept is an eight-axis diagram. On the basis of various concerns and project objectives, the definition of each axis will be different. E-concept spider diagram is an environmental product assessment tool that uses a flexible set of criteria.

Some criteria that can be used include:

- Resource efficiency (such as material efficiency and energy efficiency)
- Fulfillment of needs
- Satisfaction of customer needs
- Sustainable use of renewable
- Avoidance of hazardous substances
- Waste and emissions
- Recyclability
- Cost efficiency
- Product aesthetics
- Longevity

10.2 Evaluation method

To construct an E-concept spiderweb diagram, a set of criteria is defined and assigned to the axes of the spider web diagram (see figure 10.1). Different product aspects will then be assessed and graded with ratings according to the set of criteria.



Aspect Ratings		
Very bad	=	0
Bad	=	1
Not good	=	2
Moderate	=	3
Better	=	4
Good	=	5
Very good	=	6

Figure: 10.1 Eight-axis E-concept diagram.

10.3 Result interpretation

These eight criteria are all divided into seven ratings from 0 to 6. “0” means that aspect has very bad environmental impact while “6” is very good for environment. By marking and connecting dots on each axis, an environmental profile can be generated.

10.4 Points to be noted

The E-concept spiderweb diagram is not a mathematical instrument. The area enclosed, therefore, is dependent on the sequence of assigning criteria to each axis. Besides, the area within the spider web diagram is not used as a measure of environmental compatibility. The E-concept spider diagram is generally used for comparison with a reference product rather than for individual assessment.

10.5 Example

For example, the following set of eight criteria is applied to compare two rice cookers (1&2).

Figure 10.2 the rice cooker 1(L) and 2(R)

The following set of criteria is applied to compare two rice cooker’s environmental performance:

- Material efficiency in production
- Avoidance of hazardous substance
- Weight
- Safety
- Use of packaging
- Energy efficiency in use
- Durability
- Recyclability

Table 10.1 Environmental performance of the two rice cookers regarding defined criteria

Products Criteria	Rice cooker 1	Rice cooker 2
Material efficiency in production	Moderate (3)	Better (4)
Avoidance of hazardous substance	Moderate (3)	Moderate (3)
Weight	Good (5)	Not good (2)
Use of packaging	Not good (2)	Moderate (3)
Safety	Moderate (3)	Better (4)
Energy efficiency in use	Moderate (3)	Better (4)
Durability	Moderate (3)	Good (6)
Recyclability	Moderate (3)	Good (6)

Scale used: (Very bad=0; Bad=1; Not Good=2; Moderate=3; Better=4; Good=5; Very Good=6)

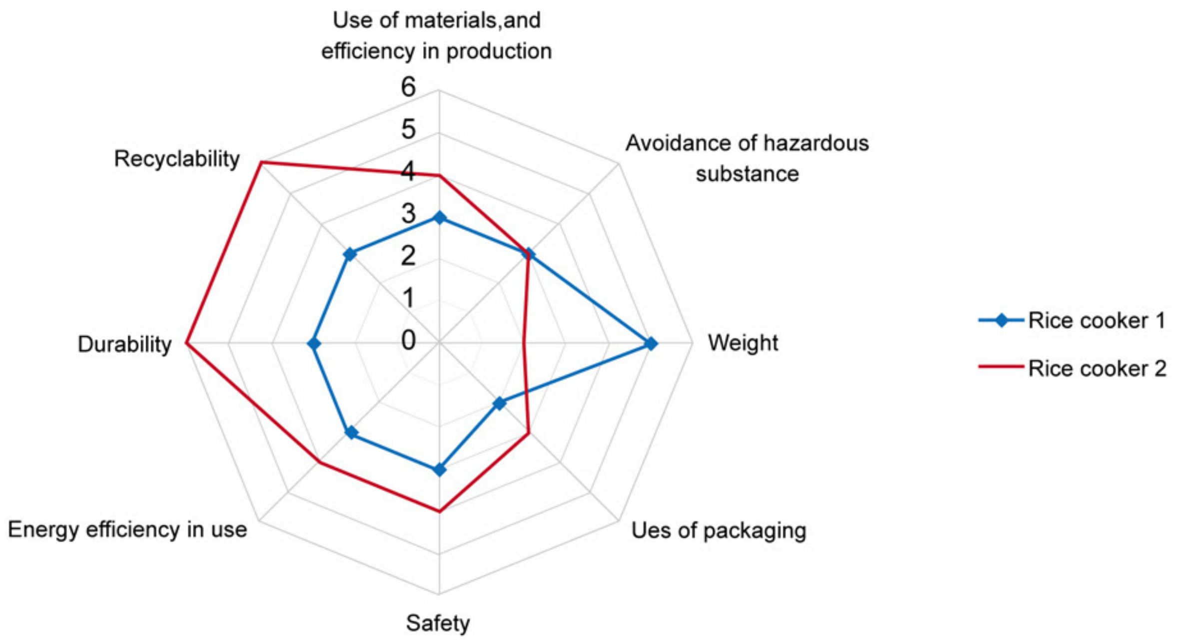


Figure 10.3 E-concept spiderweb diagram of the rice cooker 1 and 2

From the E-concept spiderweb diagram, it shows the comparison on overall environmental performance of rice cook 1 and rice cooker 2. The overall environmental performance of rice cooker two is better than rice cooker 1.

Spider-web Diagrams

10.6 Strengths

- Highly flexible for all types of product as users can set criteria based on their needs.
- Definition and number of axes depends on the project focus and scope as well as customer and company requirements.
- More than two products/designs/solutions can be compared.

10.7 Weaknesses

- The ‘spider diagram’ is not a mathematical instrument. It is not sensible to use the size of the area within the environmental profile line as a measure for environmental compatibility.
- The size of the area depends on the order of the criterion on the spokes. If the order is changed, the area differs.
- The distance from the origin is a measure for fulfilling the chosen criteria, not the area endorsed.

10.8 Applicable areas

- Types of product: All.
- Product life cycle stages: Use of raw material, manufacturing, packaging and distribution, use and end of life stages.

11 Life-Cycle Design Strategy Wheel (LiDS)

11.1 Background

Life-cycle design strategy wheel, also called LiDS wheel, is a qualitative tool used for product brainstorming. This tool was developed by Carolien van Hemel and Han Brezet for the UNEP Ecodesign Manual. Since strategies familiar to product development are defined in the LiDS wheel, different ideas can be generated by investigating pros and cons of both short-term and long-term strategies. On the other hand, the wheel can act as an ecodesign-oriented creativity technique to select improvement options for product and ecodesign ambitions for company systematically. Generally speaking, LiDS wheel serves as a framework to present current, desired and realizable environmental profile graphically.

11.2 Evaluation method

Life-cycle design strategy wheel classifies different ecodesign strategies with the linkage of five major stages of product life cycle to eight axes of the wheel. Figure 11.1 is the life-cycle design strategy wheel. The eight strategies are new concept development, selection of low-impact material, reduction of material usage, optimization of production techniques, optimization of distribution system, reduction of impact during use, optimization of initial lifetime, optimization of end-of-life system.

Figure: 11.1 Life-cycle design strategy wheel (LiDS wheel).

Moving clockwise round the wheel from strategies 1 to 7 shows the sequence of the product life cycle from raw material to end-of-life. When looking at strategies 1 to 7 in anti-clockwise direction, the product level of complexity is changing from very complex (product system) to relatively simple (product components). Figure 11.2 shows the relationship between product levels, ecodesign strategies and product life cycle stages. Strategies 1 to 7 are some improvement options aimed at achieving structural and radical solutions with substantial reduction in environmental impact. The strategy for new concept development is given a symbol @ since its nature is different from strategies 1 to 7. Strategy @ does not relate to any stages of product life cycle but leads directly to a new product concept.

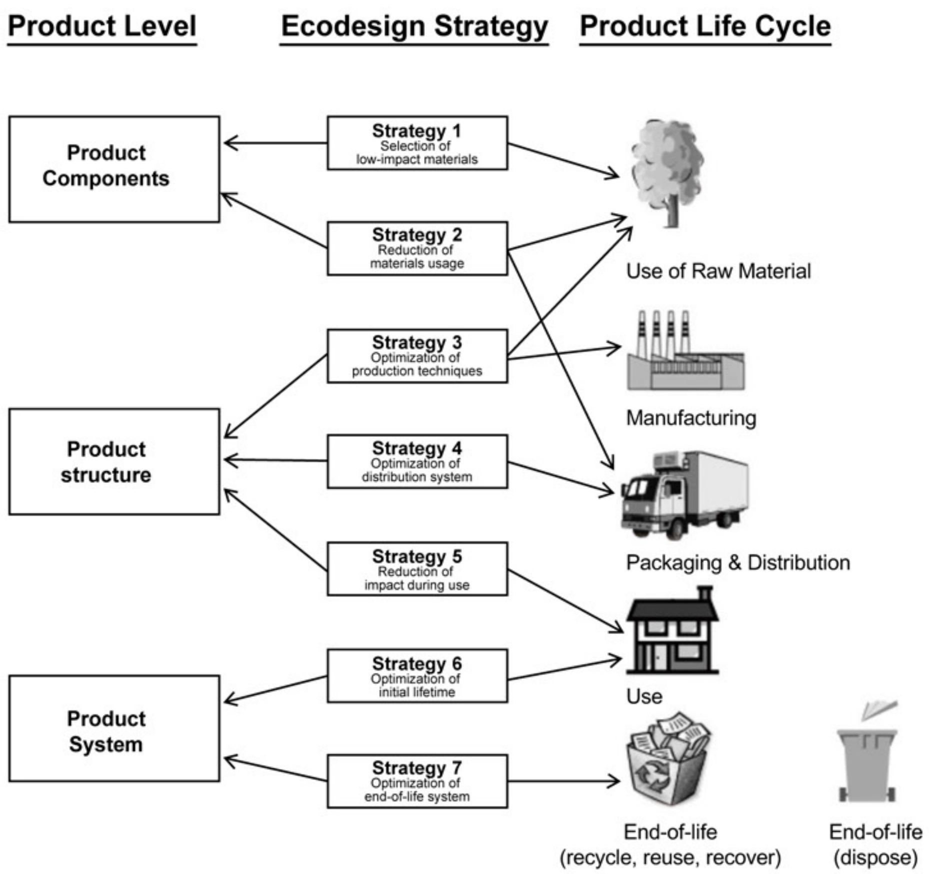


Figure11.2 The product levels, ecodesign strategies and product life cycle.

11.3 Result interpretation

To assess a product, the degree of impact is plotted along each radial axis of the wheel with a rough five-point scale. If the assessed aspect has a lower environmental impact, the plot should be marked in the outer contour of LiDS wheel. With the help of eight strategies, the result demonstrates a clear picture of environmental improvement potential and ecodesign ambitions to design team.

11.4 Points to be noted

Although the LiDS wheel is not difficult to conduct, a more quantitative assessment method should be used as a complement to account the environmental improvements of product. On the other hand, the eight axes of the LiDS wheel are named by comparative words, for example reduction and optimization, so this method is more suitable to compare products rather than assess individual products.

11.5 Example

The following example shows how to define short term and long ecodesign strategies for a commercial coffee machine by using the LiDS wheel.

Figure 11.3 The commercial coffee machine

According to the environmental performance of an existing product, the current ecodesign strategy is determined and visualized as below.

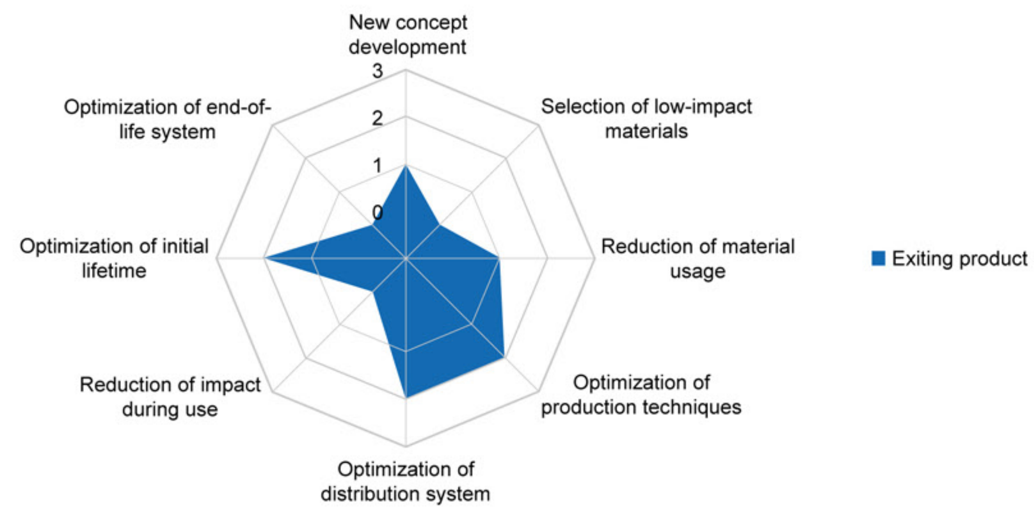


Figure 11.4 Ecodesign strategies for current implementation

The current ecodesign strategy shows that the ratings of material selection, impact of use and end of life system are 1. They have potential to be improved. For short term implementation, the design of the coffee machine can be improved. The boiler inside the coffee machine can be insulated with polystyrene to reduce heat loss from 44 percent to 7 percent. Due to the reduction of heat loss, the size of heater can also be reduced from 4 liters to 2 liters.

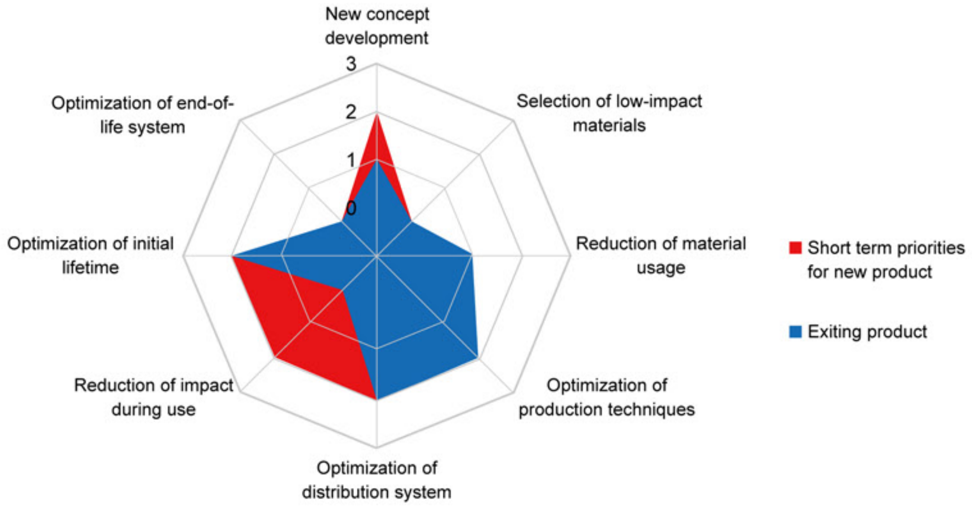


Figure 11.5 Ecodesign strategies for short-term implementation

For the long-term improvement, a logistic system can be set up for the old machine. The valuable parts can be profitably reused. Other parts can be recycled.

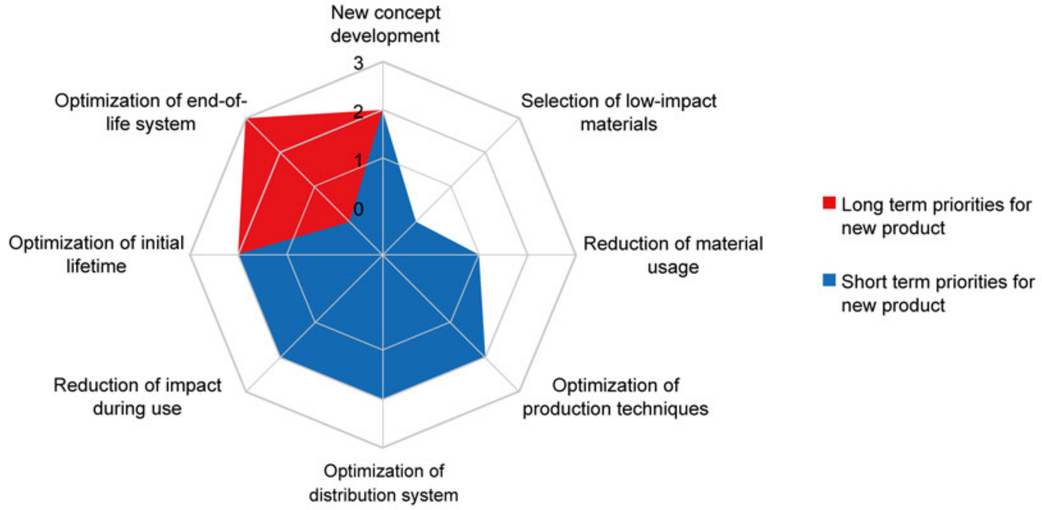


Figure 11.6 Ecodesign strategies for long-term implementation

11.6 Strengths

* Ecodesign priorities can be composed and visualized more easily.
* The establishment of ecodesign priorities can be drawn up and visualized by adding two activity lines to the ecodesign strategy wheel: short-term activities versus long-term activities. This makes it easy to communicate the ecodesign strategy both internally and externally.
* The ecodesign strategy wheel can be used for different purposes and at different times in the ecodesign process.
* It serves as a frame of reference for establishing the ecodesign strategy.
* It provides an overview of environment improvement potential which may be useful in preventing the design team from taking and locking onto one direction only.

11.7 Weaknesses

* Criteria used in this method are fixed and they do not include any customer specifications and requirements.
* According to the assessment procedures, a reference product is needed.
* No guidelines or standards are provided for grading the level of each strategy, and different results may be generated for different users.
* The starting point of the EcoDesign strategy wheel is the information from the the EcoDesign checklist and the MET matrix, which means it will be more time consuming.

11.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Use of raw material, manufacturing, packaging and distribution, use and end of life stages.

12 Material Input per Service Unit (MIPS)

12.1 Background

Material input per service unit (MIPS) is a quantitative method which was developed by Friedrich Schmidt-Bleek at the Wuppertal Institute for Climate in 1992. It is used to estimate environmental impacts caused by material input from products. This method is similar to the traditional life cycle assessment approach with the "service unit" as the functional unit and "mass intensity" as a picture of environmental impact. The term "material intensity" refers to the total material and energy throughout per unit of goods or mass unit of goods which occurs during whole life cycle. The unit of material intensity is [kg/unit], for instance, [kg/kg] [kg/kWh]. "Service unit" is a measurement unit that is set at the beginning to relate all data in order to compare different product variants. Thus, it should be formulated as a general term and can reflect all important aspects and product alternatives.

The concept of material intensity per service unit is based on the opinion that fewer materials used, less environmental impacts ensues. This concept can also be used to optimize resource productivity (eco-efficiency) of goods and infrastructures. Actually, MIPS is a targeted and practicable indicator of precautionary environmental protection. With the aid of MIPS data, a rough assessment can be made to identify environmental impacts of products by comparing material and energy intensities related to mass units and service units during throughout whole life cycle. Material intensity per service unit can be applied at several levels, for example, products, processes, services or service systems, enterprises, households, regions and national economies. The time needed for completing this assessment depends on the complexity of the assessed unit and data availability.

12.2 Evaluation method

To construct an MIPS analysis, energy inputs are firstly converted into units of material expenditure. Environmental impacts are then expressed into total material inputs with respect to the actual potential units of service. MIPS calculations proceed in seven independent steps:

Step 1: Definition of aims, objectives and service unit

Before starting any assessments, the aims and objectives should be defined first. Since comparison of various products in MIPS analysis is based on the service unit, all numerical values should be defined generally.

Step 2: Representation of process chain

A life cycle diagram is then made to observe the relations between the individual process steps under scrutiny. The diagram serves as a structure for the MIPS calculation. By using the life cycle diagram, information gaps and a overall impression of whole process can be represented easily.

Step 3: Compiling of data

In this step, all necessary natural inputs and outputs are gathered. It is the most important but time-consuming step in MIPS analysis. Since some specialized knowledge and data may not be available, estimations should be made if necessary. The gathered data is documented and kept in a data sheet.

Step 4: MI from "cradle-to-product"

On the information of step 3, the material input (MI) can be calculated by linking the gathered data with the MI factor, if available. The material input equation is shown below:

Material Input (MI) = Input Amount (Amount) x Material Intensity (MIT)

The values of material intensity can be obtained from some online tables on the Internet with unit of [kg/unit]. Table 12.1 shows part of the MIPS table from the Wuppertal Institute.

Table 12.1 MIPS table of Wuppertal Institute.

Material		MI-Material [ton/ton]	MI-Air [ton/ton]	MI-Water [ton/ton]
Crude Oil		1.2	4.3	0.008
Concrete, B25		1.3	3.4	0.04
Glass		3	17	0.7
Metals				
Copper	Primary	500	260	2
	Recycled	9.5	105	0.7
Nickel		141	233	40.85
Stainless steel		21	45	5.5

Steel	Primary	7	45	1.3
	Recycled	3	57	0.5
Aluminum	Primary	85	1378	9
	Recycled	3	60	0.5
Plastic				
PVC (powder)		8	118	0.7
PE		5	60	2.1
Renewable Resources				
Fiberboard		11	23.5	0.55
Roundwood		5.5	9.5	0.15

Besides using the equation above, a calculation sheet (table 12.2) can be used for calculating the material input.

Table 12.2 Calculation sheet for calculating material input.

Calculation Sheet: Date refer to:														
Name Substance or pre-product	Unit	Amount	Abiotic Material		Biotic Material		Earth Move--ments		Water		Air	
			i	ii	i	ii	i	ii	i	ii	i	ii
		Total:										

Parametric methods

Remarks for table 12.2:

- i refers to MI factors in unit [kg/kg] or [kg/other unit].
- ii refers to the material input which is calculated by multiplication of the material intensity with the input amount.
- Total refers to the calculation of overall result per category by the addition of the part results.

Step 5: MI from "cradle-to-grave"

Besides the manufacturing stage, use and end-of-life are also the major causes of resources consumption. Since resource consumption depends on the users and products or services, material input for use and end-of-life stage is calculated separately from step 4.

For the use stage, operational inputs such as energy, water, oil, spare parts, and cleaning materials are added in the calculation. In addition, energy and material inputs in the end-of-life stage are counted against the total number of service units provided by the product or service during its use stage. Since the material input (MI) is related to the input amount, a smaller final MI value from step 4 and 5 means lower environmental impact.

Step 6: MI to MIPS

In step 6, the material input (MI) is related to the service unit. Material intensity per service unit is calculated by dividing the total material input (MI) from step 4 and 5 by the number of service units that defined in step 1. The unit of MIPS is [weight of moved nature/service] or [weight of moved nature/product]. The equation for calculating MIPS is as follows:

$$\text{Material Intensity per Service Unit (MIPS)} = \frac{MI_{step\ 4} + MI_{step\ 5}}{\text{NO.of Service Unit}}$$

Step 7: Results Interpretation

Concerning the comparison significance, the percentage of material inputs is analyzed. Based on calculated MIPS values for both the products or services for comparison, the preferred alternatives should be determined. Besides, appropriate optimizing strategies can now be selected.

12.3 Result interpretation

The MIPS method can be used to measure natural resource consumption in five categories, viz. abiotic and biotic resources, earth movements， agriculture and silviculture, water and air. Abiotic resources refer to non-renewable resources like minerals, fossil energy sources and soil excavations. Biotic resources refer to renewable resources like plant biomass. Earth movements include mechanical movements and erosion. Water includes surface, ground and deep ground water used by humans. Air is calculated when it is used in combustion processes or chemically or physically transformed. The concept of total material requirement (TMR) used in many cases in macro-level statistics, refers to the sum of abiotic and biotic resources and erosion.

12.4 Points to be noted

Before calculating MIPS, several data are required. Since MIPS involves the use of resources from raw material extraction to product end-of life (cradle-to-grave), all technically caused movements of materials are calculated and examined back to the resource-consumption. However, the examination is very extensive, and the pre-process-chains can be very long and branched. By applying boundaries to the system, those processes and material flows which have negligible influence on the final assessment can be ignored. In view of the MIPS concept, material inputs are divided into five main categories: abiotic raw materials, biotic raw materials, earth movement, water, and air. Categories, definitions and material inputs of each category are shown in table 12.3.

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Table 12.3 Material input categories in MIPS.

Category	Definition	Material Inputs
Abiotic raw materials	All unprocessed abiotic raw materials that are taken directly from nature.	· Mineral raw materials (use extraction of raw materials, such as ores, sand, gravel, slate, granite) · Fossil energy carrier (amongst others coal, petroleum oil, petroleum gas) unused extrac tion (overburden, gangue etc.) · Soil excavation (e.g. excavation of earth or sediment)
Biotic raw materials	All vegetable raw materials taken either from cultivated or uncultivated areas and all animal raw materials from uncultivated areas before processing.	· Plant biomass from cultivation · Biomass from uncultivated areas (plants, animals etc)
Earth movement	Encompass all movements of earth in agriculture and silviculture.	· Mechanical movement · Erosion
Water	All water directly taken from natural sources.	· Surface water · Ground water · Deep ground water (subterranean)
Air	All directly extracted air as long as it is altered, either chemically or physically (aggregate state).	· Combustion · Chemical transformation · Physical transformation

12.5 Example

To illustrate the application of the MIPS, a MIPS calculation will be demonstrated in the following example of two alternative fans (1&2).

Figure 12.1 the fan 1 (L) and 2 (R)

Step 1: Definition of aims, objectives and service unit

The aim of the MIPS calculation here is a comparison of two different fans. The service unit is 10 year (assuming 20 hours per week, 48 weeks / year)

Step 2: Representation of processes chain

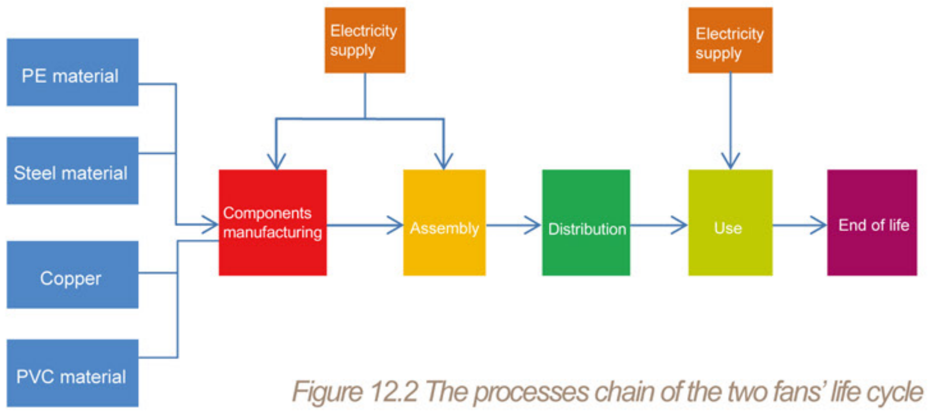

Figure 12.2 The processes chain of the two fans' life cycle

Step 3: Compiling of data
This step encompasses the following:
1.The weight analysis of the product
2.The estimation of the distribution, use and end of life phases
3.The compiling of the appropriate MI factors

Table 12.4 weight share of products

	Fan 1	Fan2
Material	Kg per appliance	
Steel (primary)	1.53	1.75
Copper (primary)	0.61	0.80
Plastic (HDPE)	1.26	1.94
Plastic (PVC)	0.34	0.45
Total	3.74	4.94

Table 12.5 distribution, Use and recycling phase

	Fan 1 (Life span: 10 Years)	Fan 2 (Life Span: 10 Years)
Distribution (Truck)	150km	200km
Use (energy consumption)	30 watt power	40 watt power
Use (energy consumption/ year)	30W X 20 h/Week X 48 week X 10 years = 0.288MWh	40W X 20 h/Week X 48 week X 10years = 0.384MWh
Recycling (Truck)	50km	50km

Step 4: MI from "cradle-to-product"

Table 12.6 the MI factors of materials (partial)

Material	MI-Material [ton/ton]	MI-Air [ton/ton]	MI-Water [ton/ton]
Metals			
Copper (Primary)	500	260	2
Steel (Primary)	7	45	1.3
Plastic			
PVC (powder)	8	118	0.7
PE	5	60	2.1
Plastic			
Electrical power	4.7	83.1	0.6
Transportation			
Truck	0.107	0.927	0.1

Table 12.7 MI from "cradle-to-product" of fan 1

Calculation Sheet: Fan 1 **Date refer to:**												
Name Substance or pre-product	Unit	Amount	Abiotic Material		Biotic Material		Earth Move--ments		Water		Air	
			i	ii	i	ii	i	ii	i	ii	i	ii
Steel (Primary)	kg	1.53	500	765					2	3.06	260	397.8
Copper (Primary)	kg	0.61	7	4.3					1.3	0.793	45	27.45
PVC (powder)	kg	1.26	8	10					0.7	0.882	118	148.68
PE	kg	0.34	5	1.7					2.1	0.714	60	20.4
		Total:		781						5.449		594.33

Total MI from "cradle-to-product" of fan 1 = 781.05kg + 5.449kg + 594.33kg = 1380.83kg

Table 12.8 MI from “cradle-to-product” of fan 2

Calculation Sheet: Fan 2 **Date refer to:**												
Name Substance or pre-product	Unit	Amount	Abiotic Material		Biotic Material		Earth Move- -ments		Water		Air	
			i	ii	i	ii	i	ii	i	ii	i	ii
Steel (Primary)	kg	1.75	500	875					2	3.5	260	455
Copper (Primary)	kg	0.8	7	5.6					1.3	1.04	45	36
PVC (powder)	kg	1.94	8	15.52					0.7	1.358	118	229
PE	kg	0.45	5	2.25					2.1	0.945	60	27
		Total:		898.4						6.843		747

Total MI from “cradle-to-product” of fan 2 = 898.37kg + 6.843kg + 746.92kg = 1652.133kg

Step 5: MI from “cradle-to-grave”

Table 12.9 MI from “cradle-to-grave” of fan 1

Calculation Sheet: Fan 1 **Date refer to:**												
Name Substance or pre-product	Unit	Amount	Abiotic Material		Biotic Material		Earth Move- -ments		Water		Air	
			i	ii	i	ii	i	ii	i	ii	i	ii
Distribution(Truck)	tKm	150	0.107	16.05					0.927	139.05	0.1	15
Use (Energy consumption)	MWh	0.288	7	2.016					83.1	23.9328	0.6	0.1728
Recycling (Truck)	tKm	50	0.107	5.35					0.927	46.35	0.1	5
		Total:		23.42						209.33		20.17

Total MI from “cradle-to-grave” of fan 1 = 23.416kg + 209.33kg + 20.17kg = 252.916kg

Table 12.10 MI from “cradle-to-grave” of fan 2

Calculation Sheet: Fan 2 **Date refer to:**												
Name Substance or pre-product	Unit	Amount	Abiotic Material		Biotic Material		Earth Move- -ments		Water		Air	
			i	ii	i	ii	i	ii	i	ii	i	ii
Distribution(Truck)	tKm	200	0.107	21.4					0.927	185.4	0.1	20
Use (Energy consumption)	MWh	0.384	7	2.688					83.1	31.9104	0.6	0.2304
Recycling (Truck)	tKm	50	0.107	5.35					0.927	46.35	0.1	5
		Total:		29.438						263.66		25.23

Total MI from “cradle-to-grave” of fan 2 = 29.438kg + 263.66kg + 25.23kg = 318.32 kg

Step 6: MI to MIPS

$$\text{Material Intensity per Service Unit (MIPS)} = \frac{MI_{step\ 4} + MI_{step\ 5}}{\text{NO.of Service Unit}}$$

Materials Intensity per Service unit (MIPS) of fan 1 =(1380.83kg + 252.916kg) / 10 years = 163.299 kg / year

Materials Intensity per Service unit (MIPS) of fan 2 =(1652.133kg + 318.32 kg) / 10 years = 197.045 kg / year

Step 7: Results Interpretation

From the result, fan 1 has relatively lower material intensity per unit compared with fan 2. The environmental burden of fan 1 is less than fan 2.

12.6 Strengths

* MIPS carry a comparative advantage is that the potential for product and process innovation can be retained for further development.
* MIPS analysis enables the quantitative determination of the material and energy input required for a product across its entire life cycle.
* In the environmental impact of a product, it is sensible to ignore product outputs like waste streams, emissions or hazardous substances. This makes the method easier to use compared with LCA.

12.7 Weaknesses

* The degree of perfection is not high. The underlying reason maybe the practical use and calculation of MIPS highly depends on the feasibility and quality of the data.
* As this method is based on the assumption that for a first assessment of the environmental impact of a product, the result will be totally different if the assumptions are inaccurate or unverified.
* The calculation of the material input for a MIPS assessment is complex.
* The application of the MI factors is limited, as the data is not valid for every situation, and the data would be not kept to date. If special process chains need to be taken into account, MI factors are generally not available in public databases or publications.
* The gathering of data and verification is the most important and frequently the most time consuming step in MIPS analysis.
* In MIPS analysis, the assessment is restricted to the total tons or kg of materials that act as inputs throughout the product's life.

12.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Raw material extraction, manufacturing, use, and end of life stages.

13 Eco-indicator 99 (EI99)

13.1 Background

Eco-indictor (EI) of a material or process is a numerical value that used to express the environmental load of a product or process system based on the use of material and its amount from the life cycle. This EI system is a type of simplified life cycle assessment tool which represents the environmental performance by weighting the mass for materials, treatment processes, transport processes, energy generation processes, and disposal scenarios. It is a general and quick environmental indication for designers or product managers to analyze and compare their design alternatives. With the use of the eco-indicator value, the problem areas from the environmental point of view for the product can be quantified for improvement.

Based on the concept of the eco-indicator, two sets of standard values have been developed: eco-indicator 95 (EI-95) and eco-indicator 99 (EI-99). The working principles of EI-95 and EI-99 are similar; the methodology of both sets of standard value conformed to ISO 14042. Since there are several improvements in the set of EI-99 values, EI-99 is described here instead of EI-95.

13.2 Evaluation method

The set of standard eco-indicator 99 values can be divided into five major areas, they are: material, production process, transport process, energy generation process, and disposal scenario. The absolute value of the points (or milli-points) for material, production process, transport process, energy generation process are generally positive. It means all of them have negative impact on the environment. In the disposal scenario, some figures yield negative eco-indicator values. This situation occurs when the waste treatment produced by-products can be recycled or reused. In addition, when energy and material flow can be reclaimed from the waste, it will yield a negative point since it is regarded as a positive impact on the environment.

The four main steps to calculate the final eco-indicator value (called eco-points) for a product are: (1) establish the purpose of the Eco-indicator calculation, (2) define the life cycle and process tree, (3) quantify materials and processes and (4) fill in the form.

Step 1: Establish the purpose of the Eco-indicator calculation

Similar to other types of life cycle assessment, the assessment purpose and system boundaries should be set in the initial stage. Users are required to define whether the analysis focuses on one specific product or several products in comparison. In addition, it is important to define the level of accuracy as it may affect the results in the later stage.

Step 2: Define the life cycle and process tree

After defining some issues at the beginning of the assessment, users are required to have a general concept about the processes throughout the life cycle. Since product description and life cycle outline are important for life cycle assessment, a schematic overview related to the product system is needed. To present the information clearly, a process tree is used. Figure 13.1 shows an example of process tree diagram for a coffee machine.

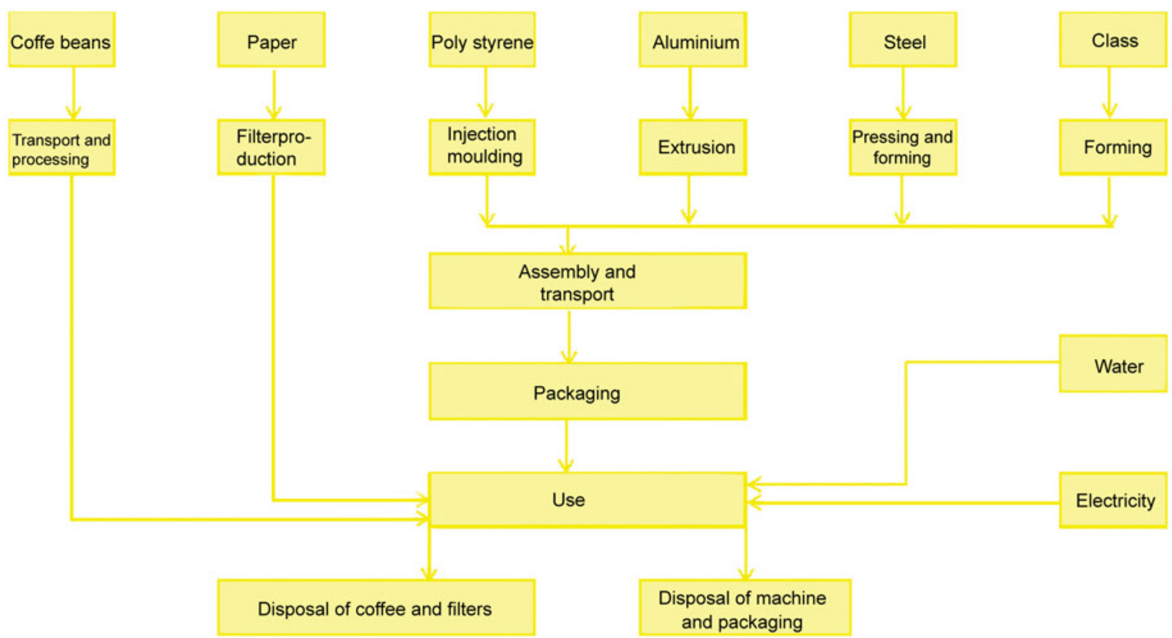

Figure 13.1 example of a simplified process tree for the life cycle of a coffee machine.

Step 3: Quantify materials and processes

To conduct a life cycle assessment for an existing product, it is important to gather all the information, such as materials and processes, for further investigation. The best way to collect the data is to disassemble the product. Users can also get the information from design specifications. Based on the parts and components, users are required to build a bill of materials (BOM) which includes part description, types of material used, amount, and units etc. In addition, users are required to make some assumptions related to the product life cycle. The assumptions may be concerned with product lifetime, frequency of use, and transportation distance. Some relevant units (e.g. kg for raw material, tkm for transportation system, Kwh for use of electricity) should also be set in this step.

Step 4: Fill in the form

Knowing all the information related to the product and its life cycle, a simple form used for calculating eco-indicator value can now be filled in.
Table 13.1 shows a form for calculating the eco-indicator value.

Table 13.1 table for calculating eco-indicator value for product.

Product component:	Project:		
Date:	Author:		
Notes and conclusion:			
Production (materials, processing, transport and extra energy)			
Material or process	Indicator [Pt]	Amount [Kg]	Result
Total			
Use (transport, energy and any auxiliary materials)			
process	Indicator [Pt]	Amount [Kg]	Result
Total			

Disposal (disposal processes per type of material)			
Material and type of processing	Indicator [Pt]	Amount [Kg]	Result
Total			
Total (all phases)			

The table used to calculate the eco-indicator value for a product is divided into three parts: production, use, and disposal. Users are required to fill in the types and amount of materials and processes in each phase of the life cycle. The relevant eco-indicator values are then found and recorded on the form.

In some cases, the eco-indicator value for a material or process may be missed in the set of standard eco-indicator values. To solve this problem, users should firstly check the contribution of that material or process on behalf of the total environmental impact. If the contribution is significant, user can substitute a known indicator for an unknown one. For instance, a user can estimate the eco-indicator value for a missing plastic since the indicator value for plastic is always in the same range. A user can also request an environmental expert to calculate the eco-indicator value for a missing material or process if it is possible. In contrast, if the contribution of a material or process is small, a user can omit it in the calculation. It is better to estimate the eco-indicator value for the missing material or process, rather than omit it.

After filling in the data, the total scores in each phase can be calculated by multiplying the amounts by the materials or processes specific eco-indicator values. The final eco-indicator value (named eco-points) for products is the sum of the totals in each phase.

Step 5: Interpret the results
The higher the value of the eco-indicator, the greater the environmental load of the product. According to the total eco-indicator values in each phase and the eco-points from all phases, the specific life cycle stage or design alternatives with the most significant environmental impact can be identified. In this step, a user should check the effect of the assumptions and uncertainties made in step 3. Users should also check whether the purpose of the calculation has been met or not.

13.3 Result interpretation

The higher the value of the eco-indicator is the greater environmental load of the product becomes.

13.4 Points to be noted

In debates about the seriousness of environmental effects, opinions are usually very diverse. This may have to do with differences in knowledge levels, but also fundamental differences in attitude and perspective play an important role.

13.5 Example

The following example demonstrates a environmental performance analysis of a cordless vacuum cleaner.

Figure 13.2 the cordless vacuum cleaner

Step 1: Establish the purpose of the Eco-indicator calculation
The purpose of this calculation is the analysis of a cordless vacuum cleaner. The input and output of each stage of the product life cycle are included in this calculation. The following figure shows the system boundaries of the vacuum cleaner.

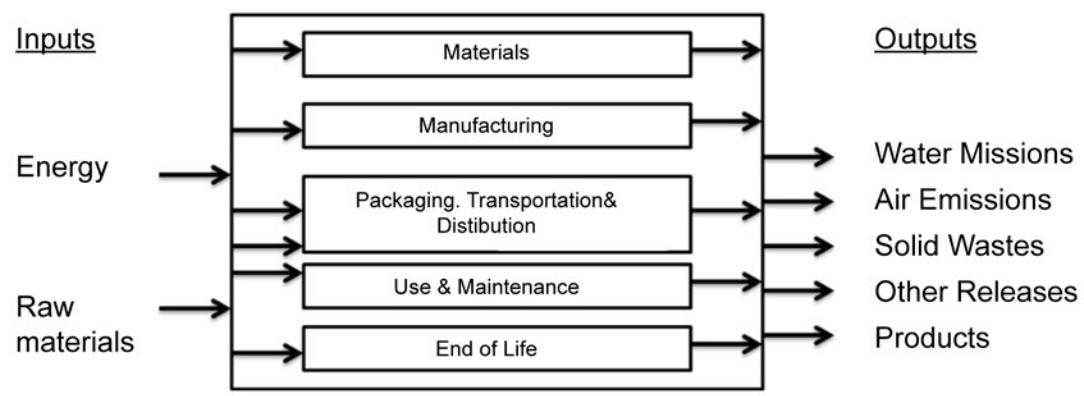

Figure 13.3 Inputs/outputs of product system throughout the whole product life cycle

Step 2: Define the life cycle and process tree

The following process tree describes the product life cycle of the vacuum cleaner.

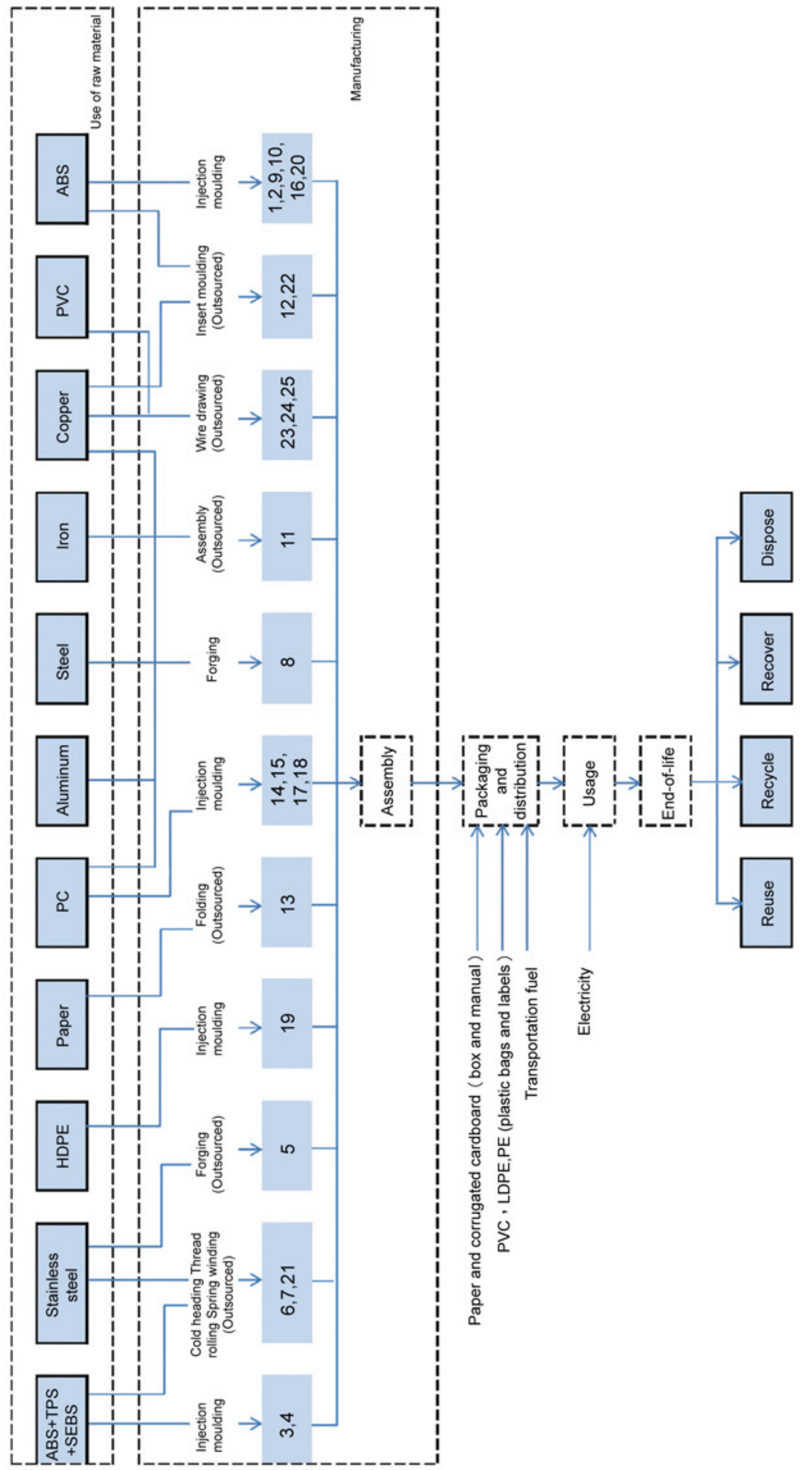

Figure 13.4 The flowchart of the vacuum cleaner's whole life cycle

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Step 3: Quantify materials and processes

Table 13.2 The bill of materials of the vacuum cleaner

Part no.	Subassembly level				Part name	Amount	Material	Weight
	0				Vacuum cleaner			
		1			Housing assembly			
1			2		Plastic Dust Cup	1	ABS	5
2			2		Plastic Dust Flap	1	ABS	195.38
3			2		Plastic Left Housing	1	ABS+TPS-SEBS	182.2
4			2		Plastic Right Housing	1	ABS+TPS-SEBS	184.8
5			2		Push Nut Washer	2	Stainless steel	3
6			2		Screw	1	Stainless steel	1
7			2		Screw	4	Stainless steel	4
			2		Release bottom assembly			
8				3	Plastic Duct Cup Release Button	1	ABS	5.5
9				3	Return Spring M3.5X6	1	Stainless steel	0.71
		1			Brush			
10			2		Brush Assembly	1	Steel	19.3
11			2		Plastic Brush Holder	1	ABS	14.72
12			2		Plastic Crevice tool	1	ABS	22.60
		1			Electrical parts			
13			2		18V DC Motor	1	Aluminum Steel Copper Iron PC	157.1
14			2		Contact Plate Holder	1	ABS + Copper	5.29
15			2		Pad Cushion (Rear)	2	PC	0.3105
16			2		Pad Cushion (Front)	1	PC	0.3105
			2		ON/OFF switch assembly			
17				3	Plastic Switch Button	1	PC	2.82
18				3	Slide switch	1	ABS + Copper	4.47
19			2		Wire 1	1	Copper + PVC	7.67
20			2		Wire 2	1	Copper + PVC	7.67
21			2		Wire 3	1	Copper + PVC	7.67
		1			Filter assembly			
22			2		Filter (Paper 935 X 58mm)	1	Paper	9.40
23			2		Plastic Filter Frame	2	HDPE	20.40
		1			Fan assembly			
24			2		Plastic Fan (Top)	1	PC	5.6
25			2		Plastic Fan (bottom)	1	PC	11.4

Step 4: Fill in the form

Table 13.3 EI-99 value of the vacuum cleaner

Porduct or component: Vacuum cleaner		Project: Ecodesign project 001	
Date: 21 June,2008		Auther: Wong	
Notes and conclusion: EI value for missed material type in database is replaced by similar material			
Production (materials,processing, transport and extra energy)			
Material or process	Indicator [Pt]	Amount [Kg]	Result
ABS	400	0.2538	101.52
ABS+TPS-SEBS	400	0.3670	146.8
Injection moulding ABS	21	0.6208	13.0368
Aluminum	60	0.0314	1.884
Copper	1400	0.0211	29.54
HDPE	330	0.0207	6.831
LDPE	360	0.0081	2.916
Blow foil extrusion PE	2.1	0.0288	0.06048
Iron	240	0.0157	3.768
Paper	960	0.2852	273.792
PC	510	0.0336	17.136
Injection moulding PC	44	0.0336	1.4784
PVC	240	0.0071	1.704
Calendering PVC foil	3.7	0.0071	0.02627
Stainless steel	910	0.0237	21.567
Steel	86	0.0979	8.4194
Corrugated cardboard	69	0.3997	27.5793
		Total [mPt]	658.059
Use (transport, energy and any auxiliary materials)			
Process	Indicator	Amount	Result
Electricity LV Europe (UCPTE)	33 mPt/kWh	14.56kWh	480.48
Truck 16t (factory to pier)	34 mPt/tkm	100km	13.6 (*1)
Tanker oceanic (PRd pier to US East Coast pier)	0.8 mPt/kWh	13000 km	30.86 (*2)

Rail transport (pier to department store)	3.9 mPt/kWh	600 km	7.5 (*3)
Truck 16t (pei to department store)	34 mPt/tkm	200 km	27.2 (*4)
		Total [mPt]	559.64
Disposal (disposal processes per type of material)			
Material and type of processing	Indicator [Pt]	Amount [Kg]	Result
Recycling ABS	-240	0.3104	-74.496
Recycling PC	-240	0.0168	-4.032 (*6)
Recycling PE	-240	0.0144	-3.456
Recycling PVC	-170	0.00355	-0.17112
Recycling Paper	-1.2	0.1426	-1.658755
Recycling Cardboard	-8.3	0.19985	-24.552 (*5)
Recycling Ferro metals	-720	0.0341	-4.256
Incineration ABS	-5.3	0.0608	-0.658048
Incineration PC	-5.3	0.12416	-0.035616 (*6)
Incineration PE	-19	0.00672	-0.10944
Incineration PVC	37	0.00576	0.05254
Incineration Paper	-12	0.00142	-0.68448
Incineration Cardboard	-12	0.05704	-0.95928
Incineration Steel &stainless steel	-32	0.07994	-0.77824 (*5)
Incineration Aluminum & other type of metals	-110	0.02432	-1.5004
Landfill ABS	4.1	0.01364	0.763584 (*6)
Landfill PC	4.1	0.18642	0.041328
Landfill PE	3.9	0.00213	0.033696
Landfill PVC	2.8	0.08556	0.005964
Landfill Paper	4.3	0.11991	0.367908
Landfill Cardboard	4.2	0.03648	0.503622
Landfill Steel &stainless steel	1.4	0.02046	0.051072
Landfill Aluminum & other type of metals	1.4	0.02046	0.028644 (*5)
		Total [mPt]	-116.102521 (*7)
		Total (all phases)	1101.596479

Remark:

*1 EI value for 16 ton truck (40% loading) is 34 mPt per tkm.
Since the weight of whole product (product and packaging) is around 1.6 kg, each time of travel can distribute:
1 ton x 0.4 / 1.6 kg = 250 units of VC
EI value for each unit of VC for this transportation system
= 34 mPt/tkm x 100 km / 250 units = 13.6 mPt

*2 EI value for oceanic tanker (54% loading) is 0.8 mPt per tkm.
Since the weight of whole product (product and packaging) is around 1.6 kg, each time of travel can distribute:
1 ton x 0.54 / 1.6 kg = 337 units of VC
EI value for each unit of VC for this transportation system
= 0.8 mPt/tkm x 13000 km / 337 units = 30.86 mPt

*3 EI value for rail transport (50% loading) is 3.9 mPt per tkm.
Since the weight of whole product (product and packaging) is around 1.6 kg, each time of travel can distribute:
1 ton x 0.5 / 1.6 kg = 312 units of VC
EI value for each unit of VC for this transportation system
= 3.9 mPt/tkm x 600 km / 312 units = 7.5 mPt

*4 EI value for 16 ton truck (40% loading) is 34 mPt per tkm.
Since the weight of whole product (product and packaging) is around 1.6 kg, each time of travel can distribute:
1 ton x 0.4 / 1.6 kg = 250 units of VC
EI value for each unit of VC for this transportation system
= 34 mPt/tkm x 200 km / 250 units = 27.2 mPt

*5 As there is a lack of EI value for other types of metals (such as copper and iron), the EI value of "recycling aluminum" and "incineration aluminum" are used instead.

*6 As there is no data for the end-of-life treatment of VC, the data for end-of-life for PS is used instead since the production value for PC and PS is closer than the other types of plastics in EI-99 database.

*7 According to the WEEE directive, there should be 70% for recovery and 50% for recycling in the small household appliance. Therefore, all types of material involve in the end-of-life stage of VC is divided in this percentage.

Step 5: Interpret the results

The results generated from EI-99 show that the EI values for production, use and disposal are 658.059 mPt/kg, 559.64 mPt/kg and -116.102521 mPt/kg. As higher values of eco-indicator have higher environmental impacts, the production has the highest environmental impacts when compared to the use and disposal of vacuum cleaner.

13.6 Strengths

* Objective and systematic life cycle assessment tool.
* A single value indicator can give a measure of the total environmental improvement of a product.
* Environmental Products can be compared quantitatively.
* The eco-indicator allows for an analysis of the relative contribution of different impact category indicators without any weighting.
* It has enabled one single score to be calculated for the total environmental impact based on the calculated effects.
* Data have been collected in advance for the most common materials and processes.

13.7 Weaknesses

* Some specific materials and processes are lack in the set of standard eco-indicator 99 values.
* The eco-indicator may not be useful for all countries since most of the eco-indicator values are developed based on average European figures.
* No accepted standard for weighting the relative importance of different impact areas so that they can be combined to produce a meaningful figure for "total environmental impact".

13.8 Applicable areas

* Types of product: All.
* Product life cycle stages: Manufacturing, use and end of life stages.