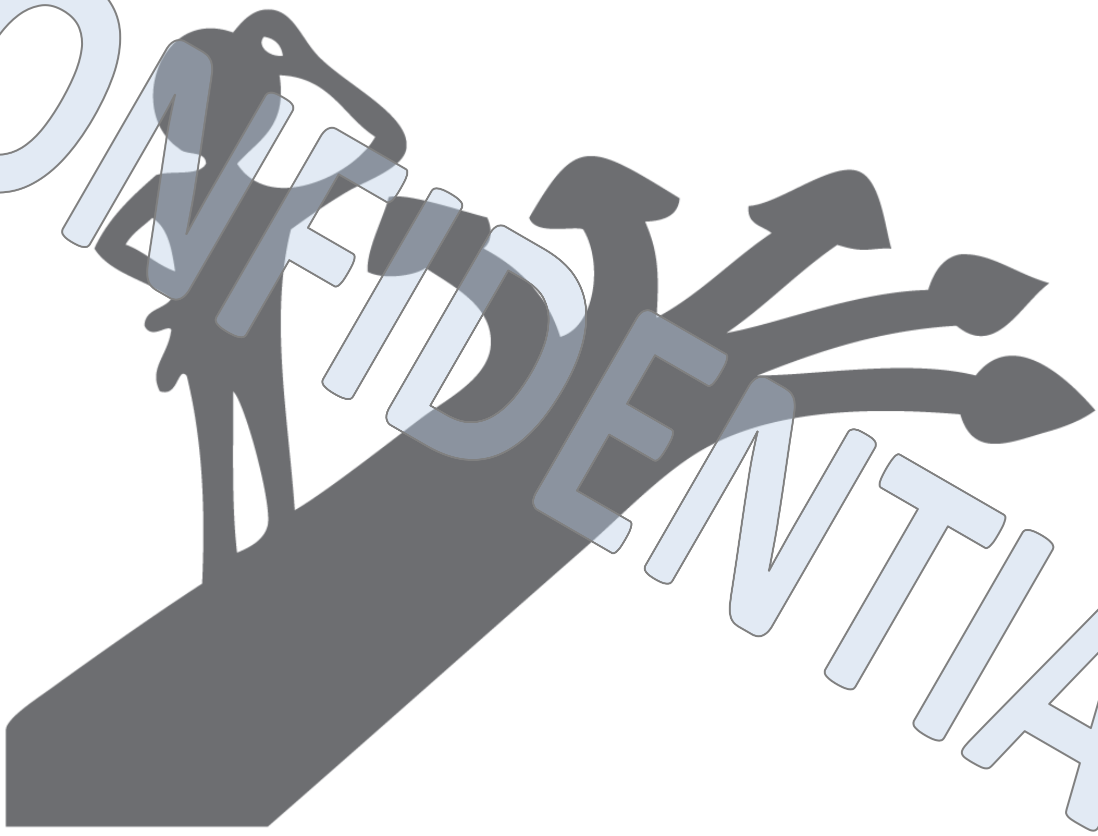
2010

PHILIPS & UNIVERSITY OF TWENTE

Marieke Brouwer
Industrial Design Engineering



SUSTAINABLE MATERIAL SELECTION

Sustainable material choices for Philips appliances
Confidential

Responsible organisations

Philips Consumer Lifestyle
Innovation Domestic Appliances
Oliemolenstraat 5
9203 ZN Drachten
Tel: 0031 0512 599111

University of Twente
Bachelor Industrial Design Engineering
Postbus 217
7500 AE Enschede
Tel: 0031 053 4899111

PHILIPS

UNIVERSITY OF TWENTE.

Author
M.T. Brouwer

Student number
S0139343

Study
Industrial Design Engineering at the University of Twente.

Supervisors
Philips: Ing. Dirksen, M.

University of Twente: Ir. Toxopeus, M.E.

Examination board
prof.dr.ir. de Boer, A., Ir. Toxopeus, M.E., Ing. Dirksen, M. and Ir. Purvis, E.

Publication date
28 september 2010

Number of copies
5

Number of pages
59

Number of appendices
9

This report is written in the scope of the Bachelor Assignment for Industrial Design Engineering and is one of the outputs of the KWR arrangement between Philips and the University of Twente. This report will remain confidential until ____________. Copies will be stored at Philips and the University of Twente.

Table of contents

Summary

The goal of the assignment was to find a way to implement the Granta CES Selector in the IDA department for making sustainable material choices. Therefore information of the Philips product development process, the Philips sustainability procedures was needed and more familiarity with the software program was needed. As a case study for selecting sustainable materials the SENSEO was used.

The Philips product development process consists of different projects that are successive. In every project different milestones have to be passed and every milestone has specific deliverables. The projects go from conceptual to realisation and execution. During the production process the material choice develops. PP, ABS, PC and PA 66 are the most common material choices. The 'technical' material selection is done by the product engineers and function developers. Philips has to live up to the standard sustainability legislations. Next to that Philips has a management strategy for developing more sustainable appliances. With Green Focal Areas Philips defines the 'Green Products' that are made.

The Granta CES Selector is a software program for material selection. This software program has an extensive material database, based on material types, suppliers, etc. Of each material general, engineering and eco data can be found in datasheets. These properties can be used for material comparison and selection. There are different material selection strategies possible with the Granta CES Selector. The Granta CES Selector also includes a tool for a quick life cycle analysis: Eco audit.

In methods for sustainable design, targets for sustainable materials can be found. When combining the different methods the most important goals for sustainable materials are: minimizing environmental impact throughout the whole life cycle, closing the material loop and no toxic substances. In practice some problems may occur that need to be solved when using sustainable materials in Philips appliances. Tools for sustainable material selection are EcoScan, Granta Eco Audit and the Granta CES selector. These tools need different input, have different calculation methods and have a different type of output.

A case study has been done on the materials of the SENSEO. The conclusions of this case study have been used for a more general approach towards sustainable materials choices for Philips appliances within a product development process. The conclusion is that the Granta CES Selector is suitable to use in the earlier stages of the Philips product development process. With a step-by-step plan the product engineers and function developers can make well founded decisions on material choice. With this step-by-step plan the Granta CES Selector is implemented in the product development process at Philips.

Samenvatting

This is the Dutch Summary.

Het doel van de opdracht was het vinden van een manier om de Granta CES Selector in IDA te implementeren voor het maken van duurzame materiaalkeuzes. Informatie over Philips productontwikkeling, de duurzaamheidprocedures en de Granta CES Selector zijn daarvoor gebruikt. Een case study over duurzame materiaalkeuzes voor de SENSEO is gedaan.

De Philips productontwikkeling gebeurd in meerdere projecten die elkaar opvolgen. Tijdens deze projecten moeten meerdere milestones worden behaald. Bij elke milestone moeten er bepaalde documenten worden afgeleverd. De projecten gaan van conceptuele ontwikkelingen richting uitwerking en realisatie. De materiaalkeuze ontwikkelt zich tijdens het ontwikkelingsproces. PP, ABS, PC en PA 66 zijn de meest gebruikt materialen. De 'technische' materiaalkeuze wordt gemaakt door de 'product engineers' en de 'function developers'. Philips moet zich houden aan de standaard wetgeving voor duurzaamheid. Daarnaast is er een managementstrategie voor de ontwikkeling van meer duurzame producten. Doormiddel van 'Green Focal Areas' wordt bepaald welke producten groene producten zijn.

De Granta CES Selector is software voor materiaal keuzes. De software heeft een uitgebreide materiaaldatabase, gebaseerd op materiaaltypes, leveranciers, etc. Algemene, engineering en eco data kan worden gevonden in de database. Deze eigenschappen kunnen worden gebruikt voor het vergelijken en selecteren van materialen. Er zijn verschillende strategieën voor het selecteren van materialen mogelijk in de Granta CES Selector. De Granta CES Selector heeft ook een tool voor een snelle life cycle analysis: Eco Audit.

In de methoden voor duurzaam ontwerpen kunnen richtlijnen voor duurzame materialen gevonden worden. Wanneer de verschillende methoden worden gecombineerd kunnen de meest belangrijke doelen voor duurzame materialen gevonden worden. Deze zijn: het minimaliseren van de milieu-impact over de hele levenscyclus, het sluiten van de materiaalkringloop en geen giftige stoffen. In de praktijk kunnen er problemen voorkomen bij het gebruik van duurzame materialen in Philips producten. Tools voor duurzame materiaalselectie zijn EcoScan, Granta Eco Audit en Granta CES Selector. Deze tools hebben een ander input nodig, gebruiken verschillende berekenmethodes en hebben een verschillende output.

Er is een case study gedaan over de materialen van de SENSEO. De conclusies van deze case study zijn gebruikt voor het ontwikkelen van een meer algemene strategie voor duurzame materiaalkeuze voor Philips producten in het productontwikkelingproces. De Granta CES Selector is goed te gebruiken in de eerdere stadia van het productontwikkelingsproces. Doormiddel van een stappenplan kunnen de product engineers en de function developers gegronde keuzes maken. Doormiddel van dit stappenplan is de Granta CES Selector geïmplementeerd in het product ontwikkelingsproces van Philips.

Preface

Around March this year I was looking for a good assignment to finish my Bachelor Industrial Design Engineering at the University of Twente. It was clear to me that the subject had to be around sustainability. In the past years during my studies I did some work on this subject and it always enjoyed me to find solutions and define methods to make products more sustainable. During that time I was already in contact with some companies searching for ways of collaboration. Then Marten Toxopeus came with the plan to contact me to Philips Innovation Domestic Appliances. The University of Twente and Philips were already starting up some projects for the KWR and sustainability was one of the subjects. When I heard about the subjects of sustainability I knew that they would have the right assignment for me. I few weeks later I was sitting in a meeting room at Philips, talking with Erica Purvis and Mark-Olof Dirksen and the collaboration was founded.

This report gives an overview of the project I worked on. I really enjoyed working on this project and besides the findings of my research I also learned a lot about the workplace, companies and other cultures (many nationalities can be found among the employees). I want to thank Marten Toxopeus for finding me this assignment and guiding me throughout the process. I also want to thank Mark-Olof Dirksen and Erica Purvis for their guidance throughout the project and the other people at Philips for the willingness to give interviews and to help.

Marieke Brouwer
Enschede, September 2010

Introduction

Philips is working on sustainability for several years. A lot of research is done on energy efficiency. The usage phase of Philips products has the biggest environmental impact. The next step is to focus on material choices. Philips has bought the software program Granta CES selector for making sustainable material choices. This assignment is based on implementing the Granta CES Selector in the Philips product development process.

One of the sustainability projects worked on is a sustainable SENSEO. In this assignment the SENSEO will be used as a benchmarking case. In the project different material scenarios are created and assessed. In this report these and some extra scenarios are compared and conclusions can be made on the sustainability of the different options. The possibilities of the Granta CES Selector will be explored.

In this report the research that is done to fulfil the assignment will be discussed. There will be started with the product development within Philips. After that, the Granta CES Selector will be discussed. Sustainable material choices based on three sustainability methods are combined to three main goals in sustainable material selection. The software tools for materials selection and sustainability are discussed and a case study is done on sustainable material choices for the SENSEO.

In Appendix 1 a list of definitions and abbreviations is given to explain the terms used in this report. In Appendix 9 the plan of approach made at the start of the assignment can be found.

1. Philips product development

The Granta CES Selector needs to be implemented within the Innovation Domestic Appliances of the Consumer Lifestyle site of Philips. This chapter gives an impression of the product development and material choices of Innovation Domestic Appliances and the sustainability procedures of Philips. This knowledge is mostly based on the overall Philips strategies (Philips, 2010) and interviews at the Beverages department.

1.1 Product development process

The Philips product development strategy contains several stages of product development. These stages will be explained in this paragraph. One of the stages will be explained more in depth. The compilation of Philips project team will also be explained.

Stages of product development

Within Consumer Lifestyle the product development is divided into different projects. A product has to pass different stages and milestones before it comes to market, figure 1.1. Every milestone has deliverables. The basis of the product development will be explained.

Figure 1.1: stages of product development

It begins with a need of consumers or a good idea for innovation. The first stage is called the Innovation Planning Process (IPP). In the IPP there will be checked if people really would want the product. When that is confirmed the Architecture Creation Process (ACP) starts. The financial and architectural possibilities will be checked by a system architect. The ACP determines if the project is feasible and fits Philips. When that is confirmed the next stage Technology and Function Creation (T&FC) will start. In the T&FC the special functions will be checked and engineered. It will be checked if it is possible to create the required functions, the most difficult and new functions will be checked.

When all those stages are passed the Integrated Product Development (IPD) will start. In the IPD process the product will be developed. It is known that it is possible to do the project, so in this stage the product will be engineered and finally be developed and launched. In the T&FC stage technology and functional research has already been done, so in the IPD this can be implemented. The first three phases can be called the conceptual phases and the IPD is about realisation and execution. At the launch date the product comes to market. Therefore a market introduction process will be started as well. When the IPD process is started a launch date will be defined. The total process from IPP to launch date takes about 2 to 3 years. In figure 1.2 the product development process of Philips is shown.

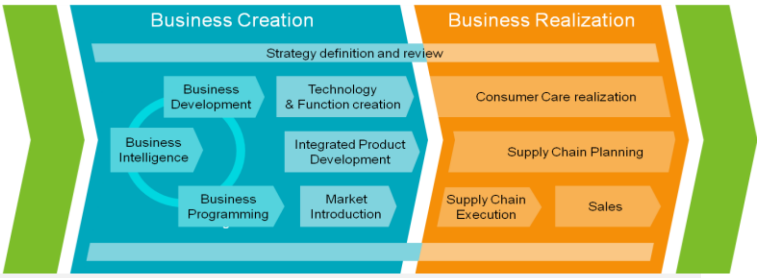


Figure 1.2: Philips product development (Philips, 2010)

IPD Project

The realisation of the products will be done in the IPD process. In figure 1.3 the Consumer Lifestyle IPD process with the corresponding milestones is shown.

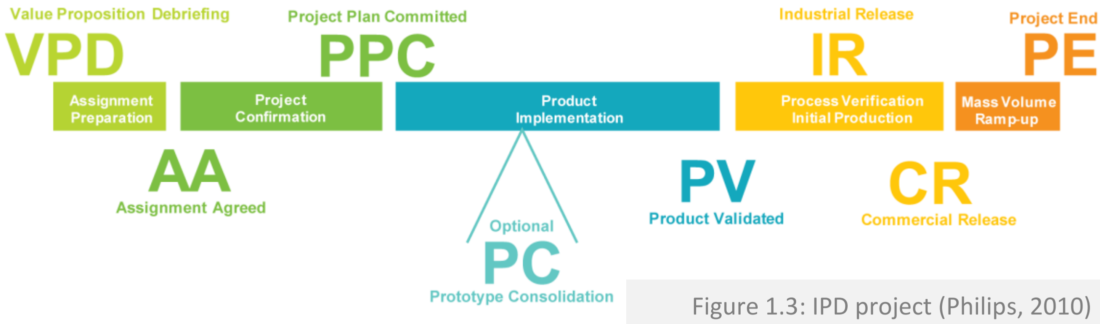


Figure 1.3: IPD project (Philips, 2010)

The optional milestone Prototype Consolidation (PC) is commonly used in IDA projects. The material choice of a project should be fixed before the Project Plan Committed (PPC) milestone. And from the PC phase there cannot be made any changes on the material choice. The material choices need to verified and checked. In the T&FC phase the first material choices can be made due to the special functions needed in a product. In the IPD project the remaining materials choices will be made.

Philips project team

Within Philips there will be worked in a multidisciplinary project team, see figure 1.4. This team will be lead by a project manager. Disciplines that are represented in a project are:

- Consumer Marketing Manager
- Development Quality
- Lead Product Engineer (Innovation & Development)
- New Product Introduction
- Application Research Centre
- Design
- Function Development
- Supply chain management
- Test & verification
- Process engineering
- Purchasing

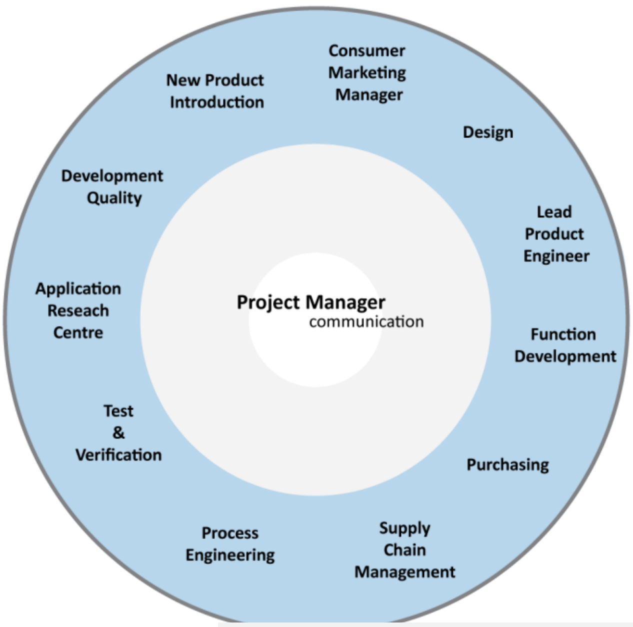


Figure 1.4: Philips project team

1.2 Material choice in product development

The material choice in a project develops throughout the different stages of the project. The most important choices in a project are made in the project team. They keep track of quality, time, money and specifications. The members of the project team all look at the material choice from their own point of view. The Lead Product Engineer is responsible for the technical design, including the material choices. Development quality will check the quality of the product, including the quality of the chosen material. Design will want the materials to have the right look and feel and so on. The project team finally makes a decision on the materials used in the product. In figure 1.5 the different points of view are stated. The materials will be listed in a bill of materials (BOM). This is a list of parts of the product, stating the materials used and the mass of the part.

Figure 1.5: Philips project team, material selection

The most used materials in Philips products are PP, ABS, PC and PA 66 (GF). In table 1.1 the most important reasons to use these materials are stated.

PP	Cheap	Low end products
ABS	Coatings can be applied	High end products
PC	Transparent	
PA 66 (GF)	High E-modulus and accurate	

Table 1.1: Philips material selection

In Philips products Borealis PP 700SA is the first choice. When specific material properties are needed another material will be chosen. This can be because of the needed stiffness, flexibility or other physical properties. But also the aesthetics and design can be a reason to use different materials.

In a Philips project there are no values for material properties stated. The materials are chosen based on the experiences in previous projects. The materials are tested in prototypes. The goal is to base material choices on sustainability. This opens new doors and gives new and more options in material choice in projects. Therefore more knowledge on the sustainability of materials is needed.

1.3 Philips sustainability procedures

Sustainability is important in Philips product development. There are legislations Philips has to live up to. There are some targets on sustainability Philips is working on for which initiatives are made and procedures are followed.

External legislation

Like every other company Philips has to live up to legislations. For sustainable products and materials the most important legislations are REACH, RoHS and WEEE. The legislations are tracked by the Sustainability Center in Eindhoven. The three types of sustainability legislations will be explained shortly.

WEEE

The EU directive on Waste Electrical and Electronic Equipment (WEEE) makes producers responsible for taking back and recycling electrical and electronic equipment. The legislation for this varies per country. This legislation now has been adopted around the world, for example in the United States. The objectives of the WEEE directive are to stop the rapid increase of WEEE send to landfill, to reduce the risk of pollution from untreated WEEE, to preserve resources by encouraging recycling and reuse and to improve the environmental performance of everyone involved in the life cycle of electrical and electronic equipment (Philips, 2010).

RoHS

RoHS is an EU directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment. New electrical and electronic equipment placed on the market with more than the agreed levels of the restricted substances will be banned by this legislation. The restricted substances are heavy metals cadmium, lead, mercury, hexavalent chromium and flame retardants polybromitated biphenyls and some polybromitated biphenyl ethers (Philips, 2010).

REACH

The newest legislation is REACH. REACH is an EU regulation on chemicals and their safe use. It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances. Producers and importers of chemicals have to register the used substances in a central database, providing information about the chemicals' properties, effects and causes and safe ways of handling them. In products the list of chemicals have to be provided if the concentrations are higher than 0.1% or if they are intended to release from the article (Philips, 2010).

Philips strategy

Philips strives to improve the environmental performance of their products and processes, and to drive sustainability throughout the supply chain. Therefore sustainability has become an integral part of their overall strategy and is a part of the management agenda. Besides the current and coming legislation on sustainability, Philips is trying to take sustainability to the next level. Not waiting for the legislations to come, but being one step ahead. In Ecovision 5 management states the targets for 2015 and in several project throughout the company sustainability is strived for.

Ecovision 5

There are identified three sustainability Leadership Key Performance Indicators (LKPIs) where Philips can provide a company direction for the longer term is this area: care, energy efficiency and materials. The targets for 2015 are fixed in Ecovision 5 (Philips, 2010).

Bringing care to people
This LKPI is mainly driven by Healthcare and is about providing solutions to improve the quality of people's lives and reduce health risks, by accessing healthcare in both mature and emerging markets.
Target: 500 million lives touched by 2015

Improving energy efficiency of Philips products
This LKPI will mainly be driven by Lighting in futher roll out of LED lighting. In healthcare and Consumer Lifestyle there will be made effort to increase energy efficiency.
Target: 50% improvement compared to 2009.

Closing the material loop
Consumer Lifestyle will be the main driver of this LKPI. It will imply improving the collection and recycling and the recycled content of our products. Philips is also committed to strengthening the legal frameworks for recycling and minimizing e-waste.
Target: Double global collection, recycling amounts and recycled materials in products by 2015 compared to 2009.

Regulated substances list
Philips has a list of substances that are not supposed to be in the Philips products. Some materials can be in the products in very small amounts. This list of substance is called the regulated substances list. The list is based on the external regulations and Philips insight. The sustainability centre updates the list.

Preferred materials list
The last Ecovision 5 target: Closing the material loop is important when looking at materials and sustainability. Closing the material loop is in line with the Cradle to Cradle philosophy. The approach of Philips in this is resource effectiveness. Therefore the materials need to be trustful and recoverable. In the preferred materials program there is the ambition to make a list of preferred materials list. This list will be made in cooperation with EPEA. The target is to list materials that are trustful and recoverable. The trustfulness of the materials will be checked by looking at the toxicity of the used substances and the hazard that this can bring. The recoverability of the materials is similar to the recyclability of the material. This includes the physical and economical possibilities to recycle the materials from Philips products.

PVC and BFR free
Philips project teams are trying to be PVC and BFR free. It is not an official Philips policy yet, because in some parts it is hard to achieve. For instance, PVC in cord sets, it is obligatory to use PVC for cord sets due to legislations. Research is being done that goes in the direction of PVC and BFR free materials for specific parts.

EcoScan
EcoScanLife 3.1 is a software program for the Life Cycle Assessment of products used by Philips. The output of the program is a histogram of the EI 99 indicator score, mass or CO2 footprint of the product throughout different life phases. These phases are presented as: production, accessories, packaging, usage and disposal. It is also possible to compare products and to make pie charts. An EcoScan chart of the product should be made in different milestones of the development process. Therefore a sustainability tracking sheet is used.

Philips Green Products

Philips offers in different product ranges Green Products. This products offer a better environmental performance on one or more of the Philips Green Focal Areas of Philips, see figure 1.6. These Green Focal Areas are: Energy efficiency, Packaging, Hazardous Substances, Weight, Recycling and Disposal and Lifetime Reliability. Philips uses the Simple Switch logo, shown in figure 1.7, to make the Green Products stand out in the store. The logo indicates that the product is better for the environment in comparison with older Philips products and products of competitors.

Figure 1.6: Green Focal Areas (Philips, 2010)

To get the simple switch logo on a Philips product, it has to be identified as a Green Product. A product is identified as a Green Product if one or more of the Green Focal Areas is significantly better, resulting in a lower total environmental impact. A Green Focal Area has to be at least 10% better than a reference product. A reference product is the predecessor or two of the closest competing products (Philips, 2010).

asimpleswitch.com

Figure 1.7: Simple switch logo (Philips, 2010)

The validation of a Green Product is done internally and externally. The product will be internally validated by the Sustainability Centre as a Green Product, the Sustainability Centre is the only party allowed to provide Green Product Certificates. Annually all Green Products are validated by a third party, this is KPMG (Philips, 2010).

Green focal areas

Energy Efficiency Energy consumption accounts for the major part of the environmental impact of Consumer Lifestyle products. This is about 70-90% of the total environmental impact. In Consumer Lifestyle there is and will be worked on the energy efficiency of the products.

Packaging The environmental impact of the packaging of Consumer Lifestyle products is small compared to the energy use and the product. For packaging there will be looked at the packaging itself and the logistics. For the packaging 20-40% of the environmental burden is from the materials and production of the packaging itself and 60-80% is from the transportation.

Hazardous Substances Hazardous substances are avoided in products. The Regulated Substances List indicates which substances are banned or can only be used in small amounts. The target is to use as less hazardous substances as possible.

Weight When looking at the environment reducing the weight of products has many benefits. Reducing the weight reduced the resource consumption, the impact of the transport and the end-of-life impact of the product.

Recycling and Disposal Philips is working on the end of life strategy for their products. Recycling is the main focus.

Lifetime Reliability This Green Focal Area is specific for the Lighting sector. In Consumer Lifestyle the products undergo lifetime and durability tests, but this is not a used target for Ecodesign in this sector.

2. Granta CES selector

The Granta CES selector is a software program for material selection. This software program includes material data from different databases. Data is available on the materials itself and on the specific material from different suppliers. In Appendix 7 a guide for the Granta CES selector for Philips can be found. The information presented in this chapter is based on the Granta CES Selector software and the information available in this software program (GrantaDesign, 2009).

2.1 Environmental data

In the Granta CES selector there can be found several eco properties of the materials. This environmental data on the materials can be used to make a selection of materials used in a product. The environmental data is divided into 5 groups: indicators for principal moment, bio-data, primary material production and material recycling.

Indicators for principal component

An eco indicator gives a measure on the overall sustainability of a product or in this case a material. In chapter 3 there will be explained more about the eco indicator. The EPS value is also an indicator for sustainability. The eco indicator is founded in the Netherlands and the EPS value is founded in Sweden. More materials have an eco indicator value than an EPS value. Within Philips the eco indicator measure is used to determine the sustainability of the Philips products. This will be explained in Chapter 3. In the currents Granta CES Selector the eco indicator ’95 method is used. Philips uses the ’99 method. The indictors available in the Granta CES selector are:

- **Eco-indicator (millipoints/kg)**
- **EPS value**

Bio-data

The bio-data that is most important for the environment are:

- **Toxicity rating (non-toxic, slightly toxic, toxic, very toxic)**
- **RoHS compliant (yes/no)**
- **Food contact grades? (FDA, EU, BfR, NSF)**

In some material data sheets there is some more bio-data available. For instance, medical grades.

Primary material production

In the primary production of a material some values can be measured. When working with these numbers there should be kept in mind that these are the values for the primary production of the material. When the material is recycled the measures can differ.
These values are:

- **Embodied energy, primary production (MJ/kg)**
- **CO2 footprint, primary production (kg/kg)**
- **NOx creation (kg/kg)**
- **SOx creation (kg/kg)**
- **Water usage (kg/kg)**

Material processing

For the material processing some values can be measured as well. These are the values for the production method. These values are:

- **Energy (J/kg)**
- **CO2 footprint (kg/kg)**

Material recycling

At the end of the products life there needs to be done something with the materials. In this data there can be seen if the materials can be recycled, are biodegradable, etc. With this data a founded decision on the end of life strategy of the product can be made. The available data is:

- **Recycle (yes/no)**
- **Down cycle (yes/no)**
- **Biodegrade (yes/no)**
- **Landfill (yes/no)**
- **Recycle as fraction of current supply (%)**
- **Combust for energy recovery(yes/no)**
- **A renewable resource?**
- **CO2 footprint, recycle (kg/kg)**
- **Combustion CO2 (kg/kg)**
- **Embodied energy, recycle (J/kg)**
- **Heat of combustion (net) (J/kg)**
- **Non-recyclable use fraction (%)**

2.2 Selection strategies

With the Granta CES selector material choices can be made. The material choices can be made by using graphs. This will be shortly explained.

Excluding materials

With the Granta CES selector it is possible to set limits on the materials properties. The material that do not meet the limits will be excluded from the results. For instance, the maximum service temperature needs to be at least 80 °C. All materials with a maximum service temperature less than 80 °C will be excluded. It is also possible to select material trees for the selection. Only the materials in the tree will be used for the selection.

Bar charts

Single axis property charts can be used when only one property is important. For instance, the eco indicator of the material needs to be as low as possible. A graph can be made with on the y-axis the eco-indicator value. The chart in figure 2.1 shows which polymers are having a lower or higher eco indicator. The bars shown in which range the eco indicator of the material will be. Most properties are given per kg of material. By multiplying the material property by the density of the materials the property per volume will be given. This can be done with the Granta CES Selector. In these charts a box can be placed which includes the wanted properties. The other properties will be excluded. For instance, the eco indicator needs to be below 400 mPt. The box will include every material that is below the 400 mPt and all other materials will be excluded.

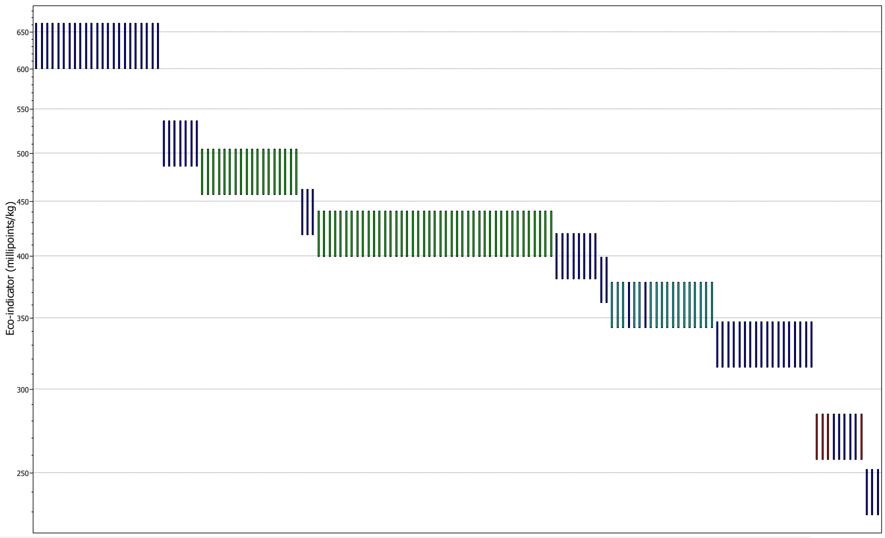


Figure 2.1: CES graph - eco indicator of polymers (GrantaDesign, 2009)

Bubble charts with trade off line

When two material properties are important a double axis chart can be made. An example of a double axis chart is shown in figure 2.2. In this chart the water usage is plotted against the embodied energy of the material. The properties on both axes should be as low as possible. Therefore a trade off line can be made (Ashby, 2009). This is a curved line across the first bubbles. The materials along this line are the best choices. This line cannot be made by the Granta CES Selector software.

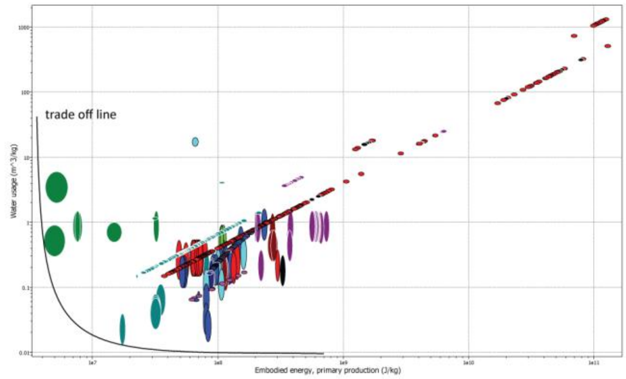


Figure 2.2: CES graph - embodied energy vs. water usage (GrantaDesign, 2009)

Performance indices in charts

A methodology for material selection is made by professor Michael Ashby (Ashby, 2009; Ashby, Shercliff, & Cebon, 2007). In the sheets in Appendix 7 in the chapter: 'Advanced selection strategies' this methodology is explained. In a performance index two material properties are used. One material property needs to be maximized and one property needs to be minimized. With the index the best materials can be selected. A performance index can be made with the performance index finder in Granta CES Selector. When the index finder is used a bar chart with the performance index on the y- or x-axis is the result. The performance index needs to be as small as possible. With the performance index finder a performance index can be set at two axes. Both performance indices need to be as small as possible, so the trade off method can be used in this case.

It is also possible to make a chart with a performance index line with the material properties on the x-axis and y-axis. A line with a scope will define which materials are best. The material that needs to be maximized needs to be on the y-axis and the materials that needs to be minimized needs to be on the x-axis. All materials above the line are the best choices. An example of a chart with a performance index line can be seen in figure 2.3. With performance indices eco properties can be connected to engineering properties. For instance: minimize embodied energy and maximize stiffness.

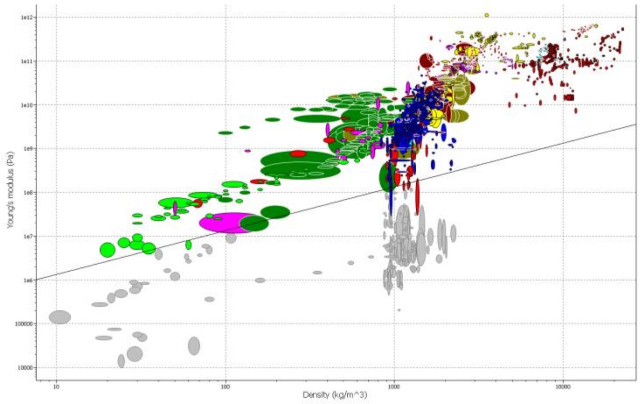


Figure 2.3: Bubble chart with performance index line (GrantaDesign, 2009)

Multiple limits and graphs for selection

With the Granta CES selector a material selection can be made. This can be done with one graph which shows the specific material data that is needed. There can also be made a decision based on multiple limits and graphs. When plotting multiple graphs with selection lines and setting some limits the materials that are excluded by one graph can be excluded in the other graphs as well. The excluded materials will disappear. When the choice is made not to remove these materials from the graph the excluded materials will turn gray.

2.3 Eco Audit

The Eco Audit of the Granta CES Selector can be found under 'tools' in the software program. The Eco Audit tool is a part of the strategy for sustainable materials of Michael Ashby. The Eco Audit tool is based on life cycle analysis of products. The life cycle analysis method is explained in Chapter 3. Instead of an eco indicator the output of this analysis are values for Energy use and CO2 production during the life time of the product. The results are shown in bar charts where distinction is made between the life phases of the product. Also the calculation steps and is given in tables. The input that is needed for the analysis is the same as needed for a standard life cycle analysis.

3. Sustainability in material selection

There are several methods for sustainable design. They all take the material choice into account. In this chapter some strategies for sustainable design will be discussed regarding to the sustainability of materials and Philips appliances. These strategies are Ecodesign, Cradle to Cradle and Life Cycle Analysis. First the points of environmental interest will be discussed and placed in the context of Philips products and finally the most important things in environmentally friendly material choices will be combined and summarized.

3.1 Ecodesign

Luttrop and Lagerstedt published a strategy for environmentally friendly design (Luttropp & Lagerstedt, 2006). In this strategy the Ecodesign strategies are summarized in ten rules for sustainable design. These rules are called the Ten Golden Rules. The Ten Golden Rules are:

1. Do not use toxic substances and utilize closed loops for necessary toxic ones.
2. Minimize energy and resource consumption in the production phase and transport through improved housekeeping.
3. Use structural features and high quality materials to minimize weight (in products) if such choices do not interfere with necessary flexibility, impact strength or other functional properties.
4. Minimize energy and resource consumption in the usage phase, especially for products with the most significant aspects in the usage phase.
5. Promote repair and upgrading, especially for system-dependent products.
6. Promote long life, especially for products with significant environmental aspects outside the usage phase.
7. Invest in better materials, surface treatments or structural arrangements to protect product form dirt, corrosion and wear, thereby ensuring reduced maintenance and longer product life.
8. Prearrange upgrading, repair and recycling through access ability, labelling, modules, breaking points and manuals.
9. Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys.
10. Use as few joining elements as possible and use screws, adhesives, welding, snap fits, geometric locking, etc. according to the life cycle scenario.

These rules should be used as a guideline for sustainable design and in some cases the rules should be adjusted to a specific product. The rules will sometimes contradict. Every case should be looked at separately to solve or handle those contradictions. Some examples of rules contradicting are:

- *For minimizing the energy use in the usage phase of the life cycle sometimes you may need to use materials for which it is not possible to use it in a closed loop. For instance a boiler, you can use a composite material that isolates very well. Then the energy use in the usage phase will become less (rule 4), but the material will not be recyclable (rule 1) and a composite is a blended material (rule 9).*
- *The investment in better treatments for a longer product life (rule 7) can increase the energy use in the production phase (rule 2). When you use coatings to protect your materials, so they will last longer, it is necessary to include some extra steps in the production phase to get the coating on the product. This will increase the energy use in the production phase of the product.*

The best way to cope with the contradictions is to look at the specific case and make compromises. Some rules will complement each other. For instance:

- *When minimizing the weight of the product (rule 3), the energy use in the transportation phase per product will be less (rule 2). This is because of the fuel that is needed to transport the product will be less.*

The conclusion that could be drawn is that the choices regarding to one of the rules can influence the performance on one of the other rules in a positive or negative way. It is important to keep these influences in mind when using the Ten Golden Rules in sustainable design.

Within Philips products the Ten Golden Rules can be used in the products development processes. Ecodesign can be found in the Philips sustainability strategy. The Green Focal areas are based on the Ecodesign strategy. The highest environmental impact of Philips products is mainly caused by the energy consumption during the use of the product. Rule 4 will be very important for those products. The toxic substances will be important in the material choices Philips makes.

Summarizing the Ecodesign Ten Golden Rules, Philips should take three things into account when looking at sustainable material choices. These points are:
- **No toxic substances**
- **Use closed loops**
- **Minimize energy throughout product life cycle**

3.2 Cradle to cradle

In 2002 Micheal Braungart and William McDonough published their book Cradle to Cradle: Remaking the way we make things (M. Braungart & McDonough, 2007). The logo is shown is figure 3.1. The strategy of Cradle to Cradle is based on the philosophy of aiming at eco-effectiveness instead of eco-efficiency.

Figure 3.1: Cradle to Cradle logo

Eco-effectiveness is about maintaining resource quality and productivity through many cycles of use, rather than seeking to eliminate waste. With the Cradle to Cradle approach they want products to be good for the environment. The Cradle to Cradle strategy is based on thinking in closed loops. The slogan 'waste equals food' declares this. Materials should be used in a closed loop life cycle. This could be a biological or technical loop. In a biological loop the material will be biodegradable and feed the plant and trees of which new products will be made. In the technical loop the products will be collected at the end of their life. The materials in these products will be used again in new products. Braungart has started a company to help other companies with the Cradle to Cradle way of working. This company is called EPEA (Environmental Protection Encouragement Agency), see figure 3.2 for logo.

Figure 3.2: Cradle to Cradle logo

In Cradle to Cradle design Braungart and McDonough distinguish products of consumption and products of service (M. Braungart, McDonough, & Bollinger, 2007). In the context of Philips a product of consumption is a coffee pad, something that may actually be consumed. After the use of a product of consumption the product is useless. Other examples of products of consumption are brake pads and shoe pads. A product of service would be the SENSEO, which serves a cup of coffee to the consumer. The product is used but not consumed itself.

Within the Cradle to Cradle philosophy Braungart and McDonough developed 5 steps to eco effectiveness (M. Braungart & McDonough, 2007). These steps are:
1. Get "free" of known culprits.
2. Follow informed personal preferences: less bad
3. The passive positive list: criteria to ban materials that are not good.
4. The active positive list: positively technical or biological nutrients
5. Reinvent: look at function rather than products

In the Cradle to Cradle strategy recycling is very important. The materials used in a product should be recycled and used again in the next product. When the material is used is losing quality, used in other products and eventually will be incinerated it is called down cycling. When the material gets a better quality it is called up cycling. Recycling is using the materials of a product throughout many lifecycles of that product. For Philips products this would be the optimal way to use their products. The High Impact Innovation Centre site has started the Preferred Materials Programme. In this program research is done on how to define a positive list for Philips products. The development of the positive list is done in cooperation with EPEA.

A way to manage materials and be eco-effective is to make a material pool (M. Braungart, et al., 2007). Four steps to make a material pooling community:
1. Creating community: identification of willing industrial partners with a common interest in replacing hazardous chemicals with technical nutrients, targeting of toxic chemicals for replacement.
2. Utilizing market strength: sharing lists of materials targeted for elimination, development of a positive purchasing and procurement list of preferred intelligent chemicals
3. Defining material flows: development of specifications and designs for preferred materials, creation of common materials bank, design of a technical metabolism for preferred materials.
4. Ongoing support: preferred business partner agreements amongst community members, sharing of information gained from research and material use, co branding strategies.

Using a material pool allows companies to pool material resources and use recycled and trustful materials.

Summarizing the Cradle to Cradle ideas Philips should take two things into account when looking at sustainable material choices. These points are:
- **No toxic substances**
- **Use closed loops and recycle the materials**

3.3 Life Cycle Analysis

In life cycle analysis the total life cycle of the product will be analysed. There will be looked at many different kinds of environmental impact. An eco indicator value measures and weights these environmental impact categories to compare different product life cycles.

Product life cycle

A product life cycle consists of all the phases a product goes though during its life. The product begins as raw materials, will be produced and used and finally end up in the garbage. In figure 3.3 a typical product life cycle for Philips products is shown.

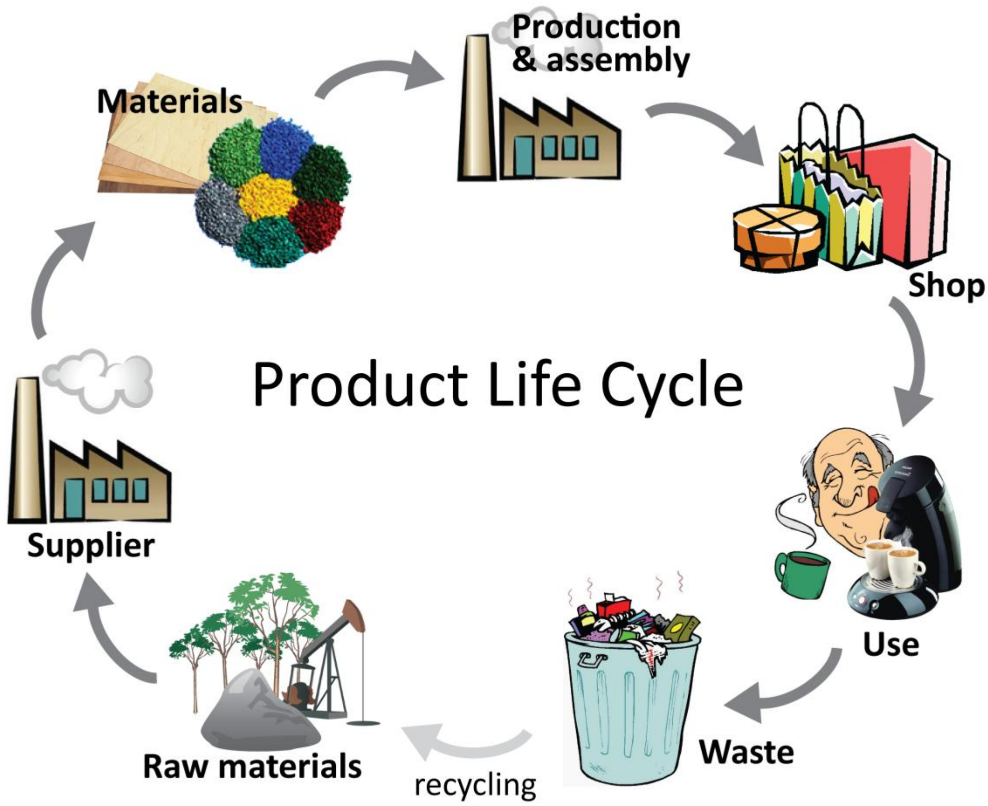


Figure 3.3: Product life cycle

Philips products start as a raw material that will be modified to a production material by a material supplier. For instance the plastic granules made from crude oil. These materials will be used in the production of parts and these parts will be assembled to a product. This product for instance a SENSEO will be sold in a shop and used by a consumer. This consumer uses the product and after use he will throw it away. This waste will be incinerated, end up in landfill or be recycled. When the product is recycled the materials of the product will be used as a raw material in the next or another product life cycle. This will close the material loop. The waste used for recycling after a consumer throws away a product is called post-consumer waste. The production waste can also be used as a raw material for new products. This is called post-industrial waste. Between all these phases the product needs to be transported. The arrows represent the transport of the product.

There are four possibilities for the end of life of products. These four end of life scenarios are reuse, recycling, incineration and dumping. When the product is used in a different way that supposed to after disposal the product is reused. Recycling is taking the materials after disposal and use them as input for the next product life cycle. In incineration the product will be burned and with dumping the product will end up in landfill (Toxopeus, 2010).

When working with a product life cycle there should be kept in mind that the overall impact of the life cycle should be as low as possible. When reducing the energy on one part of the lifecycle it can be possible that the impact at another part of the life cycle will change. When these changes increase the impact of the total life cycle, the energy reduction on the specific part of the life cycle is not feasible.

Eco indicator

An eco indicator is a number that represents the sustainability of a product. The eco indicator measures different kinds of environmental impact of a product during the whole life cycle. The environmental concerns will be measured and weighted to get one number of the environmental impact of the product. There can be made a distinction between the eco indicator '95 and '99 (Goedkoop, Demmers, & Collignon, 1996; Ministery of Housing, 2000). The numbers of these eco indicators are not comparable.

The establishment of an eco indicator (Toxopeus, 2010)

The eco indicator is a number on sustainability which is based on a selection of environmental impact categories. The environmental impact of the product is measured for the different impact categories. These numbers are compared to a reference substance; the impact of 1 kg of this substance is equal to 11 kg of the actual substance. The reference substance is called the equivalent substance. This levels the environmental impact at the different impact categories. This step is called characterisation. After the characterisation the numbers of the different impact categories will be normalized. In this step the impacts are related to a known standard. The standard of the EI '95 is for instance the average annual impact of one European. The following function for the EI '95 will arise:

$$\frac{..kg\ equivalent\ substance}{..kg\ equivalent\ substance\ per\ person\ per\ year} = ..person\ year$$

For every impact category a number in person year will be calculated. These figures are multiplied by a weighting factor. These weighting factors can be adjusted to specific needs. In figure 3.4 an overview on calculating the eco indicator is given.

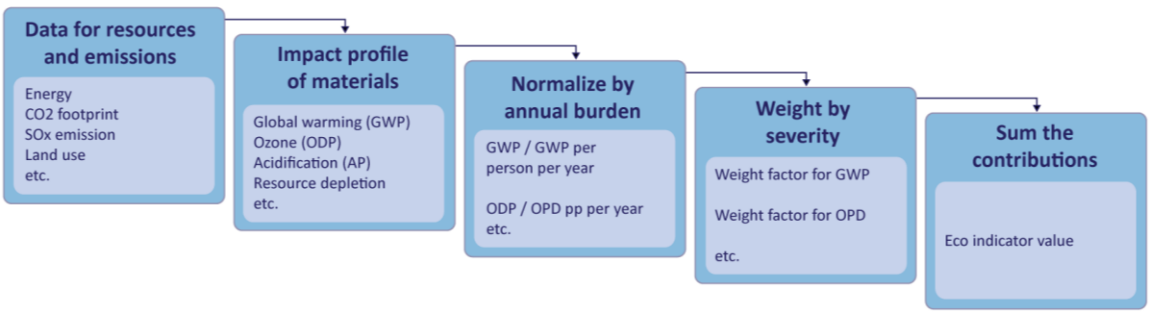


Figure 3.4: Calculating the eco indicator (TNO, 2004)

The standard categories and weighting factors of the eco indicator values are given in the table below (PReConsultants, 2010b). Usually companies apply their own weighting factors, due to the company strategy. The eco indicator of one product can be compared with the number of other products, only when the numbers are categorised, characterised, normalised and weighted in the same way with the same measures. The results of a life cycle analysis can vary when changing the weight factor or looking at an average scenario or a worst case scenario. This should be taken into account when working with life cycle analysis.

The eco indicator ’99 is measured in almost the same way as the eco indicator ’95. The difference is the characterisation. The impact categories are first assigned to tree types of damage: human health, ecosystem quality and resources. These impact categories will be normalized and weighted. The impact categories of the EI ’99 and EI ’95 are different as can be seen in table 3.1. The scores of these eco indicators are not comparable.

Eco indicator ‘99				**Eco indicator ‘95**		
Ozone layer	1	Human Health	400	Ozone layer depletion		100
Carcinogens	1			Carcinogens		10
Respiratory in organics	1					
Respiratory organics	1					
Climate Change	1			Greenhouse effect		2.5
Radiation	1			Solid waste		0
Land use	1	Ecosystem Quality	400			
Acidification/Eutrophication	1			Acidification		10
				Eutrophication		5
Ecotoxicity	0.1			Summer smog		2.5
				Winter smog		5
				Pesticides		25
				Heavy metals	Airborne	5
					Waterborne	5
Minerals	1	Resources	200	Energy resources		0
Fossil Fuels	1					

Table 3.1: Weighting factors of eco indicator

Life cycle analysis software

To do a life cycle analysis is a complex job. Therefore software programs are developed to do the life cycle analysis. All the data of the life cycle can be put in. A known software program for life cycle analysis is Simapro. Within Philips EcoScan is used. The EcoScan software is easier to use and based on Simapro. In the Granta CES selector smaller version of a life cycle analysis can be done with the Eco Audit tool of the software program.

Data from the Simapro ecoinvent database is used in EcoScan. For this an adjusted version of the eco indicator ’99 is used. The adjusted EI ’99 values are more suitable for the Philips strategy and Philips appliances. The human toxicity is replaced by an EFSOT TOX number. Carcinogens and long term emissions are left out. The metal ores have been adjusted to Philips measures.

Next year Philips will start with a different methodology, which is called recipe. This will not show in EcoScan, only the methodology behind it is different.

Influences of material choice on life cycle

The materials chosen have influence on the environmental impact of the life cycle of the product. The changes that can occur in the life cycle analysis when using a different material are stated in table 3.2.

Part of life cycle	Change due to material choice
Production	The needed production process to shape the material into a part. There might be a coating needed when certain materials are used.
Transport	The mass of product, due to the density of the material.
Usage	The isolation and conductivity of the material might vary.
Disposal	The recyclability and disposal options for the material.

Table 3.2: Influences of material choice

Summarizing the Life Cycle Analysis method, Philips should take one things into account when looking at sustainable material choices. This point is:

- **Reducing the environmental impact of the whole product life cycle.**

3.4 Sustainable materials

Three sustainability methods are examined: Ecodesign, Cradle to Cradle and Life Cycle Analysis. These three methods have some equality and some differences. When looking at sustainability in material choices there are three main goals that can be drawn from the methods, see figure 3.4. These goals are: minimizing energy consumption throughout the whole life cycle, closing the material look and no toxic substances. When these three goals are achieved a sustainable materials can be chosen.

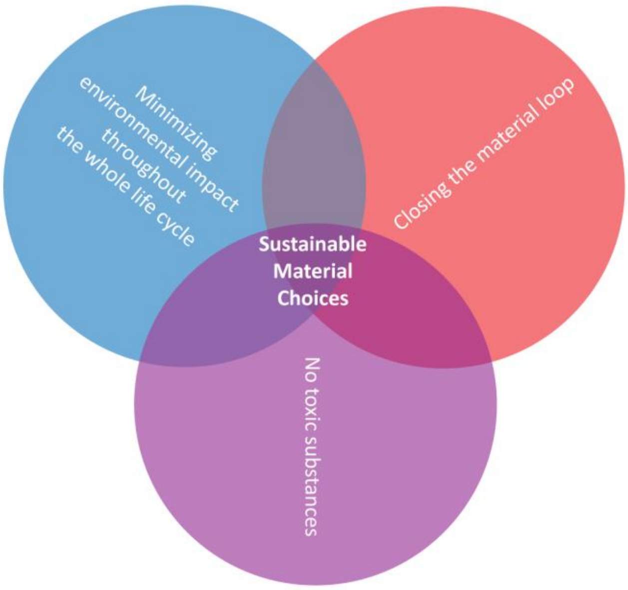


Figure 3.4: Sustainable material choices

Minimizing environmental impact throughout the whole life cycle

In Ecodesign and Life Cycle Analysis one of the targets is to minimize the energy consumption. A product always consumes energy during its life cycle. For instance, in the production phase there is energy needed to produce the material and the product. In the Cradle to Cradle strategy energy consumption is not an issue. When recycling a material energy is used to shredder, regrind and injection mould the material. There is always an environmental impact. The goal is to minimize this impact. When choosing a material it should be kept in mind that every material needs energy to be produced and processed. Minimizing this energy would be the best way to deal with it.

Closing the material loop

When closing the material loop the materials can be used several times. Therefore no new materials are needed to make the product. This will decrease the impact of the extraction of raw materials. Also the materials that are recycled do not end up as landfill, which will decrease the pressure on the scrapheap. The Cradle to Cradle method gives an approach to realize the closed material loop. In the Ecodesign rules the recycling of materials is mentioned, but there is not given an approach. When trying to close the material loop of the product life cycle of a product the Cradle to Cradle method is a good way to start.

The best would be if all materials are used homogeneous and pure. However, most materials need additives to get the right materials properties needed for safety and engineering. Coatings and fillers will pollute the recycled material. Use as less fillers, additives, coatings and other substances as possible when the technical material loop needs to be closed. Also the use of as less different types of materials will help. The product can be disassembled after use and the plastics can be recycled separately. When there are less material types, fewer material streams are needed to recycle the materials.

No toxic substances
In all methods toxic substances are mentioned. These substances may not be used in products. When choosing sustainable materials no toxic substances should be in the material. EPEA does hazard analysis on materials, looking for substances that should be banned.

List of materials
All the strategies focus on the use of materials. In Cradle to Cradle and Life cycle analysis a list of materials is needed for the analysis. When working on a product it is necessary to keep track of the materials that will be used. These materials than can be analysed.

Sustainability methods and materials for Philips
Combining the three sustainability methods and keeping the three goals based on the methods in mind is the best way to deal with sustainable materials for Philips. Working on closing the materials loop is one of the sustainability focuses of Philips. The toxic substances are banned by the regulated substances list and with the preferred materials program the trustful and recoverable materials can be chosen in the future. Beside this pay attention to the environmental impacts of the whole life cycle. Look at all the phases and all the environmental impacts. The best material choices and the most sustainable products can be made this way. Sometimes the three goals will not be in line with each other and different choices can be made when looking at the different goals. A decision needs to be made regarding the things that are found more important or based on other material properties like aesthetics or costs.

3.5 Sustainable materials in practice
In theory sustainable materials need to be in a closed material loop, have no toxic substances and will minimize the environmental impact of the product. In practice it can be very difficult to use sustainable materials. At first it is difficult to determine whether or not a material is sustainable. When a material is chosen, it will not always be feasible to use the material. In this paragraph some practical problems on recycled plastics and wood will be discussed.

Recycled plastics
Some plastics can be recycled, but it is not always feasible to recycle plastics. It has to be economically and physically feasible, before companies will start recycling plastics. When a material is used in small amount it is not feasible to start recycling it. Materials that are used in bigger amounts like PP, ABS and PC are feasible to recycle. Some companies already recycle these materials. In the current recycling systems plastic parts are shredded. The different types of plastics are separated by density. When plastics have the same or almost the same densities it is hard to separate them completely. Therefore recycled plastics can contain some other plastics.

When plastics are recycled they may not contain fillers like glass fibres. The materials that contain fillers are not recyclable, because the fillers will burn during the melting of the plastics or will pollute the recycled material. Parts in products need additives, for instance for heat resistance, due to safety regulations. Therefore materials used in products are not always pure. When a recycled material is used in the product, the additives need to be added again.

The traceability of the recycled materials is difficult. It is not always known what substances are exactly in the product. This will give some problems with the Regulated Substances List of Philips and also with the legislations on materials that need to be food approved. Therefore not all parts in a product can be made of recycled materials.

A problem the recycled plastics in the tests of Philips encounter is a smell problem. Some recycled plastics, especially from post consumer waste smell very bad. This can be a problem in the product and also during the manufacturing.

For closing the material loop there are some additional problems, beside the standard problems in recycled materials. The post-consumer waste needs to be collected and recycled again. Especially the collection is not easy to do on this point. The old products need to be selected from the waste streams. Companies like Van Gansewinkel are working on this product selection. Another possibility is inviting the consumer to deliver old products to a special collection point, but this takes an action of the consumer not everybody is willing to do. When the old products are separated from the waste steams the recycling of the product will become somewhat easier. If the product is designed in the right way the product can be disassembled and the plastics can be recycled separately. Because there is known which parts are made of which material the recycled material will not be polluted with other plastics.

Wood

Wood can be a sustainable material, because it is a renewable resource. During their life trees admit CO2, which balances out the CO2 that will be released by burning the wood. When wood is used from trees that grow fast, the material can be easily renewed. In the use of slow growing trees carefulness is needed at this moment the trees cannot grow as fast as they are cut down. The slow growing trees are having better properties than then the fast growing kind. Especially the hardness and the resistance against moulds are better. An engineering problem with wood is the swelling of wood due to heat or moisture. The natural toxics the wood contains and the sensitivity to moulds compared to plastics gives some problems in the use in products.

The company Titan Wood has a sustainable solution for the use of wood. Fast growing wood will be treated in an environmentally friendly way. The treated wood is as hard as the original slow growing woods and is better resistant against environmental circumstances. The coefficient of expansion of the material is considerably less than untreated wood. This treatment makes it feasible to use wood in products. The wood used for treatment is Pine (Pinus Radiata) and the method is Cradle to Cradle certificated. For protection against mould and dirt the wood need to be coated.

4. Software tools for sustainable material selection

In the chapters before some software tools have passed by. The Granta CES Selector discussed in Chapter 2 will be used for material selection and comparison. For the life cycle analysis EcoScan and the Granta Eco Audit will be used. These tools have different purposes and outputs. When working with different software programs is it important to keep these differences in mind. In this chapter the differences in the software programs will be discussed.

4.1 EcoScan

EcoScan is a software program for Life Cycle Analysis. With the PES2007 database from Philips materials, production processes and disposal scenarios can be inserted. The values in the database are calculated in SimaPro. In EcoScan the whole life cycle of the product will be analysed. To do the life cycle analysis a list of parts, materials and their weights is needed as input for the calculation.

The possible outputs in EcoScan are: an eco indicator value, an energy value, a global warming value and the weight of the product. The eco indicator values in the database are specific calculated for the Philips strategy. The eco indicator is a combination of different environmental impacts. In Chapter 3 this is explained. As an energy value Gross Energy Requirement (GER) is used. The value is measured in MJ and contains the summation of consumed energy throughout the life cycle and feedstock (TNO, 2004). The GER value is not in the PES2007 database of Philips, so in the Philips EcoScan calculations GER cannot be used as output. The global warming value is measured in Global Warming Potentials (GWP), expressed in kg CO2 equivalents. This is based on the extent that 1 kg substance is able to absorb heat radiation with respect to 1 kg C02 (TNO, 2004). This is the characterisation value for global warming in the steps to get an eco indicator value. This value is available in the PES2007 database and is an output for the Philips EcoScan. The weight of the product and parts is also available as output. With this software program products can be compared at different the outputs.

4.2 Granta Eco Audit

The Granta Eco Audit is a tool in the Granta CES Selector. It is part of a strategy to select sustainable materials. The Eco Audit is based on life cycle analysis. The product life cycle will be analysed and the Energy use and CO2 production during the life cycle will be calculated. The calculating steps are represented in tables and the results are available as bar charts per life phase. In the software different products cannot be compared. This can be done by exporting the data to excel. The total energy use and total CO2 production can be found in the results and with those measures products can be compared. To do the life cycle analysis a list of parts, materials and their weights is needed as input for the calculation.

The Granta Eco Audit is a part of the sustainable material selection strategy (Ashby, 2009; Ashby, Coulter, Ball, & Bream, 2009; Ashby, Miller, Rutter, Seymour, & Wegst, 2005) . The strategy is to first find out which life phase produces the most CO2 or uses the most energy. Because energy use and CO2 production are related this will mostly be the same life phase. This life phase is the phase that will be focussed on when selecting the materials. This strategy does not comply with the Philips strategy. Most Philips products will have the biggest impact during the life phase, due to the energy used in this phase. The energy consumption of product is a research area for some time now and the energy efficiency of the products is growing. The next biggest impact is in the life phase of materials and production. Therefore Philips wants to work on this phase by using sustainable materials. The Eco Audit can be used within Philips to calculate the CO2 and energy impacts of products, without following the strategy.

The database used for the calculation is the same material database as used in the Granta CES Selector.

4.3 Granta CES Selector

With the Granta CES Selector materials can be compared on their properties and make a material selection. In the comparison there will be looked at the materials only and not at the consequences of the whole life cycle. The primary production of the materials is included in the values. The labels on the materials define what materials and production process is represented by the bar or bubble.

The output possibilities of the Granta CES Selector are extensive. The selection strategies and eco data are already explained in Chapter 2. Graphs can be made on specific impact categories. The values in the primary material production are similar to the characterisation phase of a life cycle analysis that is only focussed on the material production. The eco indicator data is similar to the eco indicator only focussing on the material production after the normalization and weighting. The material properties can be graphed per mass or per volume. The volume represents the function of the product.

In comparison to EcoScan and Eco Audit the Granta CES Selector can be used without knowing what the product will look like. For EcoScan and Granta CES Selector the lists of parts and materials are needed to calculate the impact of the product. With Granta CES Selector different materials can be checked in an early stage of the design. The design decisions are still fluid, which makes it easier to change the design according to the material choices.

With the Granta CES Selector the eco information can be connected to engineering properties for materials selection.

4.4 Overview

Table 4.1 gives an overview on the important aspects to keep in mind about the different software programs. The differences in these programs define the way there should be looked at the output of the calculations.

	Input	Phase of LCA	Measures	Output
EcoScan	Part, materials, weight, production process and disposal method.	Full Life Cycle Analysis, with eco indicator as output	Life cycle	Eco indicator, CO2 and weight
Granta Eco Audit	Part, materials, weight, production process and disposal method.	Characterisation of energy and CO2	Life cycle	Energy and Co2
Granta CES Selector	Selection criteria	Characterisation or eco indicator for specific material (depends on the property used)	Only material production	All eco data that is available in the database

Table 4.1: Overview of important aspects of software programs

5. Case study: Sustainable material choices SENSEO

Within Philips some initiatives are taken to develop green products. One of the projects is working on the SENSEO. As a baseline for this project a new version of the SENSEO is taken to adjust to a green product. The shape of the SENSEO should stay the same, so there only can be made changes in the energy usages of the product and in the materials used. The advantage for this is that there don't need to be made moulds for the plastic parts. The sustainable SENSEO will be launched as a special edition.

5.1 The current SENSEO

The current SENSEO is made in different models, these can be divided into: low end, mid end and high end models. The baseline for the Sustainable SENSEO is the low end model. In this research there will be focussed on the biggest plastic parts of the product. In figure 5.1 these part are specified.

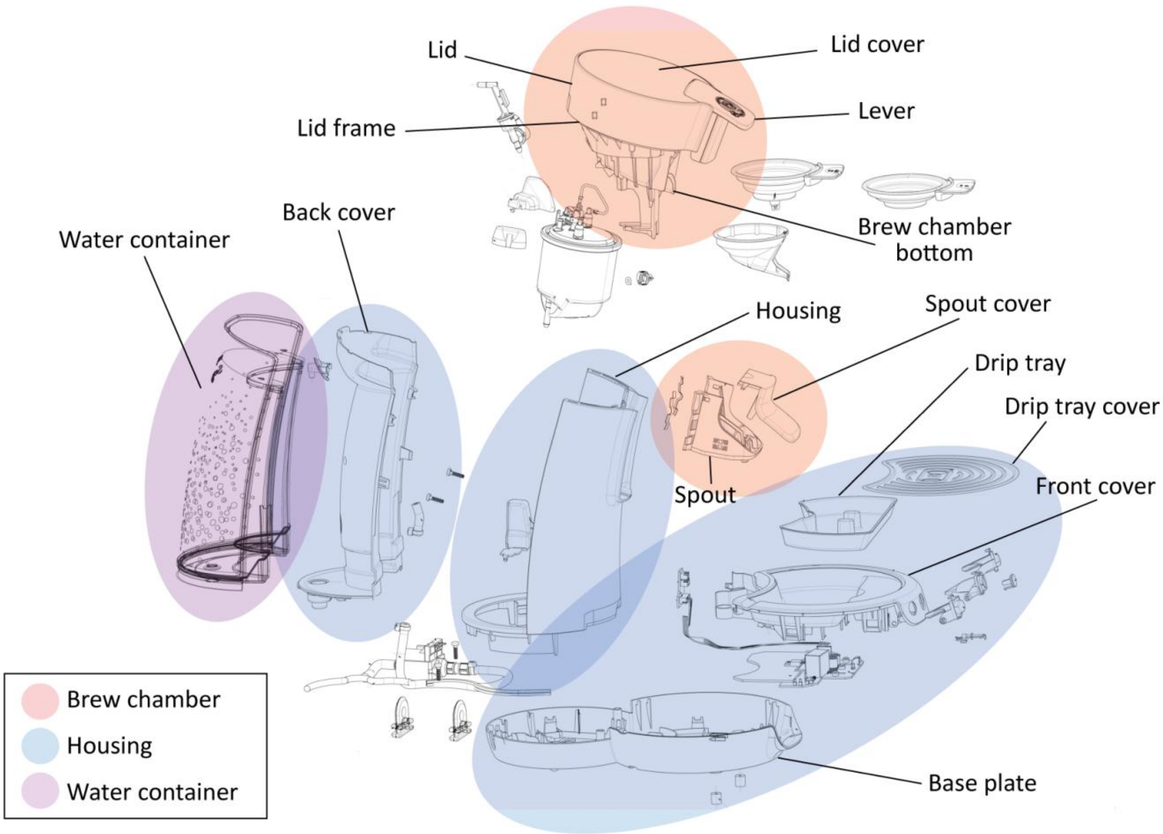


Figure 5.1: SENSEO parts (Philips, 2010)

To develop a sustainable SENSEO the materials of the current SENSEO need to be analysed. By analysing the current and new materials well-founded material choices can be made. First there will be looked at the current used materials.

The moulds for the different plastics are based on the shrinkage of the materials. So the mould could only be used again if the same materials or materials with a similar shrinkage are used. This could be recycled materials. The material that will be chosen at first is PP Borealis HF 700

SA, so the parts with another material mostly have a reason to use the different material. In table 5.1 the materials of the current SENSEO are defined by type.

Part	Material	Type
Water container		
Water container	PP	Borealis RF 365 MO transparent
Housing		
Back cover	PP	Borealis HF 700 SA
Housing	PP	Borealis HF 700 SA
Base Plate	PP	Borealis HF 700 SA
Drip tray	PP	Borealis HF 700 SA
Drip tray cover	Stainless steel	AI 430
Front cover	ABS	Terluran GP 22 natural
Brew chamber		
Lid	PP	Borealis HF 700 SA
Lid frame	PP	GB364WG
Lid cover	ABS	Terluran GP 22 natural
Brew chamber bottom	PA 66 (GF)	Ultramid A3EG6 FC natural
Lever	PC	Xantar 24 R natural
Spout	POM	Ultraform N2320 003 naturel
Spout cover	PP	Borealis HF 700 SA

Table 5.1: Materials of current SENSEO

5.2 Material changes

To make the SENSEO more sustainable the materials used in the SENSEO need to change. Not all materials in the product can be changed. In table 5.2 the parts that can be changed are coloured blue. The materials that are coloured red cannot be changed.

Part	Material	Type	Excluded because
Water container			
Water container	PP	Borealis RF 365 MO transparent	Food approval
Housing			
Back cover	PP	Borealis HF 700 SA	Food approval
Housing	PP	Borealis HF 700 SA	
Base Plate	PP	Borealis HF 700 SA	
Drip tray	PP	Borealis HF 700 SA	
Drip tray cover	Stainless Steel	AI 430	Metal
Front cover	ABS	Terluran GP 22 natural	
Brew chamber			
Lid	PP	Borealis HF 700 SA	
Lid frame	PP	GB364WG	Special properties needed
Lid cover	ABS	Terluran GP 22 natural	
Brew chamber bottom	PA 66 (GF)	Ultramid A3EG6 FC natural	Special properties needed
Lever	PC	Xantar 24 R natural	
Spout	POM	Ultraform N2320 003 naturel	Food approval
Spout cover	PP	Borealis HF 700 SA	Food approval

Table 5.2: Possible material changes

The water container, back cover, spout and spout cover cannot be changed because the parts get in touch with the water or coffee. For materials in products that have food contact there are safety regulations. The materials need to be food approved. Recycled plastics are not food approved, as stated in Chapter 3 Paragraph 3.5. So it is not feasible to change the materials that need to have food approval, this may change in the future.

The lid frame and brew chamber bottom are made of different materials then the standard PP or ABS, that is because of the properties the material needs to have. These materials will not be changed in this project.

As can be seen there are many different materials used. For recycling of the product after use, it would be best if the product is made of only one material or as few as possible. For engineering purposes this is sometimes not feasible. It would be good to take a good and critical look at the current product. Determine if it is necessary to use all these different types of materials and make well-founded decisions for the next product.

In this project there will be worked on using recycled PP, ABS and PC. These are three plastics that are frequently used and it should be feasible to recycle these materials.

5.3 Lid cover

For the sustainable material selection, the focus in this research is on the lid cover of the SENSEO, see figure 5.2. The lid cover is in one of the outer parts of the SENSEO. The current material of the lid cover is ABS. ABS is chosen in the current SENSEO because it is possible to lacquer the material. If the part will be made of PP a new mould is needed. There will be made different material scenarios to define which materials are sustainable. Therefore Granta CES Selector will be used and life cycle analysis will be done with EcoScan and Eco Audit.

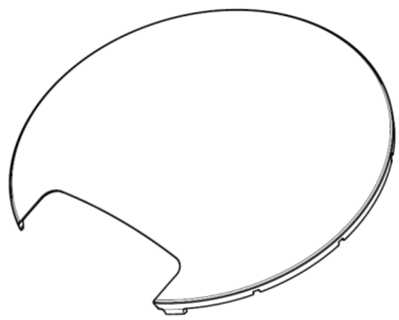


Figure 5.2: Lid Cover (Philips, 2010)

Scenarios

There are several scenarios for the SENSEO lid cover. The scenarios with the masses, production methods and disposal scenarios are defined in paragraph 5.2. The different material scenarios are defined in table 5.3.

Scenario 0	The current low end SENSEO Snake.
Scenario 1	This scenario is divided into three scenarios. All these scenarios are including recycling.
Scenario 2	Wood
Scenario 3	Glass
Scenario 4	Two scenarios of aluminium. One with virgin aluminium and one with recycled aluminium.
Scenario 5	Recycled plastic with a wooden layer. To get the wooden look and the plastic engineering properties.
Scenario 6	PP and recycling scenarios, this is a commonly used material in the SENSEO. The ABS in the lid cover will be replaced by PP in this scenario. This way ABS and PP can be compared. It would be good if there were used as few types of materials as possible. The recycling would be easier when the same materials are used. Then all the plastic parts could be shredded at the same time.
Scenario 7	PC and recycling scenarios.

Table 5.3: Material scenarios

5.4 Sustainable material selection with Granta CES Selector

There are some material directions that need to be examined. With the Granta CES selector it is possible to plot these materials is property charts. In Appendix 2 the charts for CO2, embodied energy and eco indicator ’95 are shown. An example of a property chart is the bar chart of eco indicator per volume. In figure 5.3 such a graph is shown for some proposed materials for Shrek. It is possible to select materials based on property per kg or property per volume.

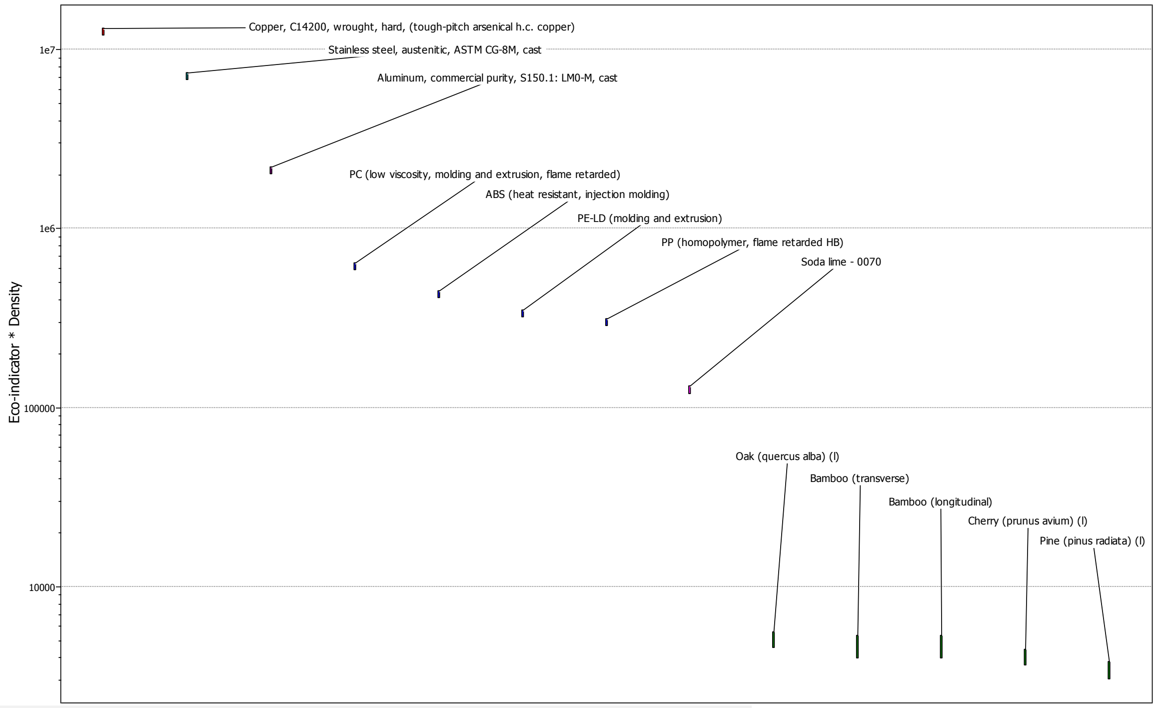


Figure 5.3: Eco indicator per volume (GrantaDesign, 2009)

Note
Recycled plastics are not available in these graphs.

Results

The results of the Granta CES Selector graphs are represented in figure 5.4 to get an overview on the sustainability of the materials in relation to each other. There are used graphs per kg and per volume. CES graphs on material recycling are made as well, because the recycled plastics are not available in CES graphs comparing materials. Some charts show materials are at almost the same measure. There the materials have the same numbers.

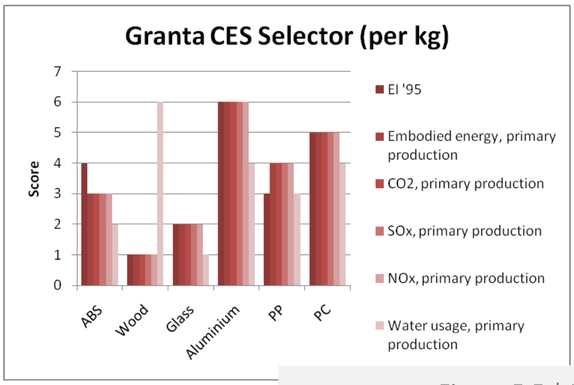
	Granta CES selector (per kg)						Granta CES selector (per volume)					
Virgin materials	EI '95	Embodied energy, primary production	CO2, primary production	SOx, primary production	NOx, primary production	Water usage, primary production	EI '95	Embodied energy, primary production	CO2, primary production	SOx, primary production	NOx, primary production	Water usage, primary production
ABS	4	3	3	3	3	2	4	4	2	3	2	2
Wood	1	1	1	1	1	6	1	1	1	1	1	5
Glass	2	2	2	2	2	1	2	2	2	2	4	1
Aluminium	6	6	6	6	6	4	6	6	6	6	6	6
PP	3	4	4	4	4	3	3	3	2	3	2	2
PC	5	5	5	5	5	4	5	5	5	5	5	4

Figure 5.4: Overview on CES results virgin materials

Note
To calculate the glass impact Borosilicate is used. The eco indicator of Borosilicate is not available; therefore Soda Lime glass is used to replace the Borosilicate.

In figure 5.4 can be seen that in most respects wood is the best material choice when looking at virgin materials. Glass is the second best material and after that the plastics. Looking at the materials per kg ABS is best, and then PP and the least good plastic is PC. The eco indicator values per kg shows almost the same order, only PP and ABS have switched. When looking at the water usage of the materials the order is totally different.

When looking at the eco indicator and embodied energy of the function of the material, so the material per volume, the order is the same as the eco indicator per kg. Measuring CO2 per volume shows that ABS, Glass and PP have all almost the same value. In SOx and NOx production ABS and PP didn't differ. When looking at the water usage of the materials the order is totally different.



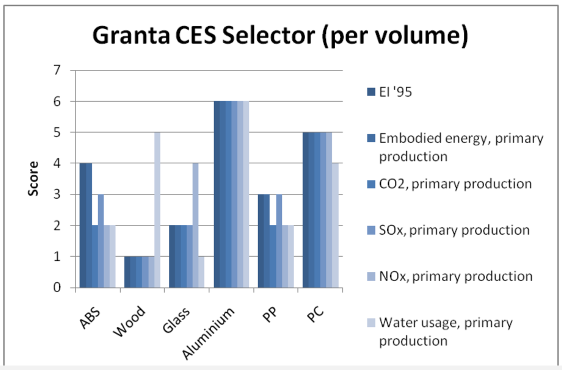


Figure 5.5 | 5.6: Overview graphs on CES results virgin materials

In figure 5.5 and 5.6 the scores from figure 6.4 are shown in graphs. This gives an overview on which materials are best and worse according to the Granta CES Selector. If all material properties are equally important the order of materials will be according to table 5.4.

Impact per kg	Impact per volume
1. Wood	1. Wood
2. Glass	2. Glass
3. ABS	3. PP
4. PP	4. ABS
5. PC	5. PC
6. Aluminium	6. Aluminium

Table 5.4: Order of materials

The only difference in the order between impact per kg or per volume is the order of the plastics; PP and ABS are switched.

Figure 5.7 shows the order of materials in material recycling. The recycling energies and the CO2 production are compared. Again there has been looked at the properties per kg and per volume. Recycling of glass has the least environmental impact, so is the best choice. Looking at the values per kg aluminium is second best, after that PC, ABS and finally PP. Looking at the values per volume the order differs for energy and CO2. Recycling PP is effective when the values are measured per volume.

	Granta CES selector (per kg)		Granta CES selector (per volume)	
Material recycling	Embodied energy, primary production	CO2, primary production	Embodied energy, primary production	CO2, primary production
Recycling ABS	4	4	3	4
Recycling glass	1	1	1	1
Recycling aluminium	2	2	5	3
Recycling PP	5	5	2	2
Recycling PC	3	3	4	5

Figure 5.7: Overview on CES results material recycling

5.5 Life cycle analysis with EcoScan and Eco Audit

For validating the results of the Granta CES selector a life cycle analysis can be done. One life cycle analysis with EcoScan and one with Eco Audit will be done. In this life cycle analysis there should be looked at the effects of the material choice to the environment. In this life cycle analysis the focus will lay on the materials, production methods and the disposal of the product, see figure 5.8.

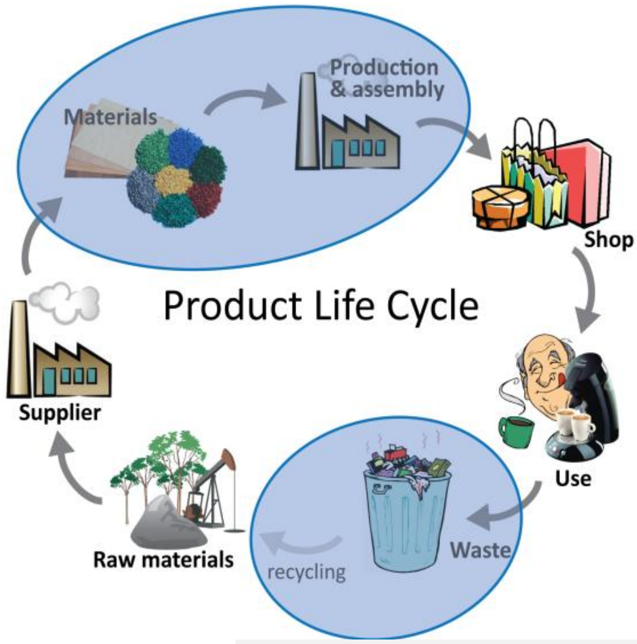


Figure 5.8: Focus in product life cycle

The phases of the product life cycle that are not taken into account are: use, accessories (EcoScan), packaging (EcoScan) and transport. Assuming these phases will not be affected by the material choice.

The use phase will not be affected when there are no changes made in the energy consuming parts of the product. Since there are no changes made in the water container, the assumption is that there won't be a change in energy loss. Another assumption is that the transport scenario won't change. Besides that the transport phase is never included in the life cycle analysis with EcoScan of Philips products, because it is not feasible to find all the information.

The life span of the product will not affect the results in both programs, because there will only be looked at materials, production and disposal.

The process flow in figure 5.9 shows the product life cycle of SENSEO. The green sections are the focus areas for the life cycle analysis. The blue areas represent the optional materials.

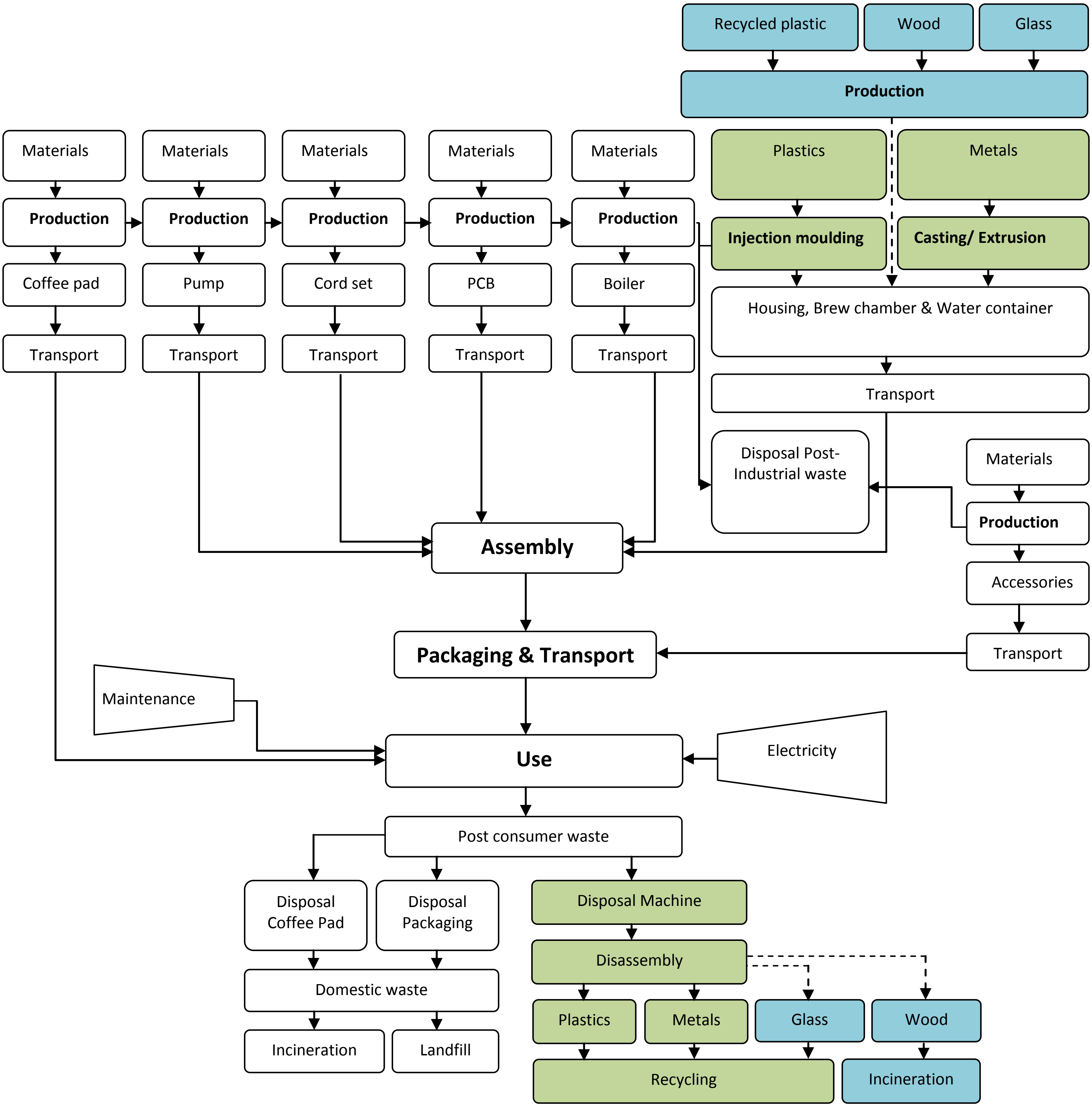


Figure 5.9: Process flow

Scenarios

The detailed scenarios for the lid cover can be seen in the table below. With the density of the different materials the mass of the lid cover is calculated. The production process and disposal will change due to the different material choices and scenarios.

	Material	Density (kg/m^3)	Mass of lid (g) (Volume: 35674.42 mm^3)	Production process	Disposal
0	ABS	1040	37,1	Injection moulding	Incineration
1a	ABS	1040	37,1	Injection moulding	Recycling
1b	Recycled ABS	1040	37,1	Injection moulding	Incineration
1c	Recycled ABS	1040	37,1	Injection moulding	Recycling
2	Wood Coating	510	18,2 5,0	Pressing Spraying	Incineration
3a	Glass	2480	88,5	Pressing	Recycling
3b	Glass	2480	88,5	Pressing	Incineration
4a	Aluminium	2685	95,8	Casting & extrusion	Recycling
4b	Recycled aluminium	2685	95,8	Casting & extrusion	Recycling
5	2/3 Recycled ABS 1/3 Wood layer	1040 510	24,7 6,1	Injection moulding Adhere	Incineration
6a	PP	908	32,4	Injection moulding	Incineration
6b	PP	908	32,4	Injection moulding	Recycling
6c	Recycled PP	908	32,4	Injection moulding	Incineration
6d	Recycled PP	908	32,4	Injection moulding	Recycling
7a	PC	1200	42,8	Injection moulding	Incineration
7b	PC	1200	42,8	Injection moulding	Recycling
7c	Recycled PC	1200	42,8	Injection moulding	Incineration
7d	Recycled PC	1200	42,8	Injection moulding	Recycling

Note

a. An assumption is that the volume of the part will not change with the different materials. The mass will change, due to the density of the materials.
b. An assumption for scenario 5 is that 2/3 of the volume is plastic and 1/3 is wood.
c. All of the life cycle analyses are of one life cycle. If the material will be recycled several times the outcome may be different.
d. To calculate the wood impact Pinus Radiata is used.
e. To calculate the glass impact Borosilicate (Eco Audit) and White glass (EcoScan) is used.

With these scenarios life cycle analysis on the lid cover will be made. Therefore the EcoScan and Eco-Audit will be used. In the next paragraphs the results of these studies are explained.

5.6 EcoScan results on eco indicator

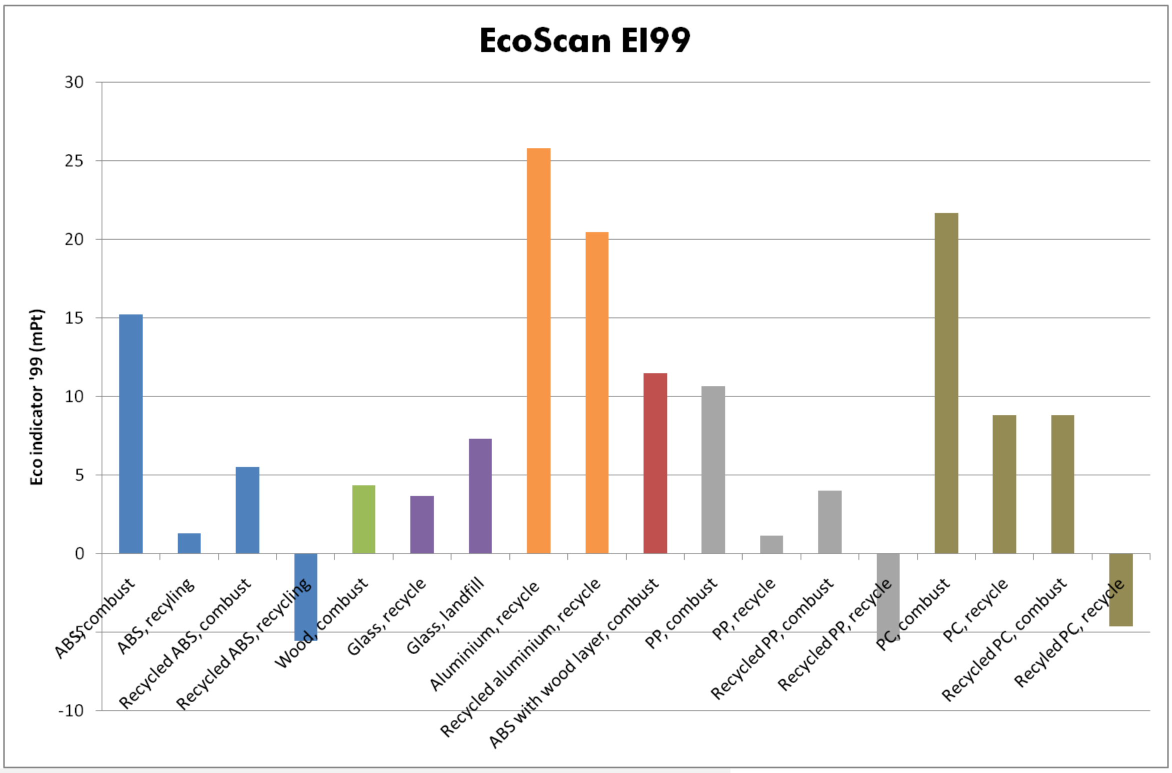


Figure 5.10: Chart of values from EcoScan Eco indicator '99

Note

f. To calculate recycled ABS 30% of the eco indicator of normal ABS is used. *
g. To calculate recycled PP 30% of the eco indicator of normal PP is used. *
h. To calculate recycled PC 30% of the eco indicator of normal PC is used. *
i. The wood production process in sawing, no extra production process is added in EcoScan. There are no values for solid wood pressing.
j. For the lacquer on the wood, the value for lacquer on plastic is used. There is no value for lacquer on wood, only on metal and plastic. Lacquer on plastic is worse than on metal, therefore plastic is chosen.
k. The PES2007 database is used for the eco indicator values. Except for the recycled plastics.

*30 % is used, because there are no number for ABS, PP and PC. For PE the eco indicator is 259 mPt and for recycled PE 78,5 mPt (PReConsultants, 2010a), this is about 30%. With the assumption that the percentage will be the same for ABS, PP and PC these numbers can be used in the calculation.

The graph in figure 5.10 shows the eco indicator '99 values of the different scenarios. The eco indicator of these scenarios is calculated by EcoScan. Keep in mind that the eco indicator values in EcoScan are Philips specific. The graph shows the eco indicator of the materials with their production process and disposal scenario. Compared to the current SENSEO lid cover most scenarios are better. Aluminium is worse, even when recycled aluminium is used. Virgin aluminium that will be incinerated is also worse. The values for recycling recycled plastics are negative. The values for recycling plastics as a disposal scenario are negative, because virgin plastics are spared by using the material again. This will be explained later. Due to comment f.,g. and h. there can be stated that the values graphed for recycled plastics are not fixed. For better results these eco indicator values need be calculated and added to the database.

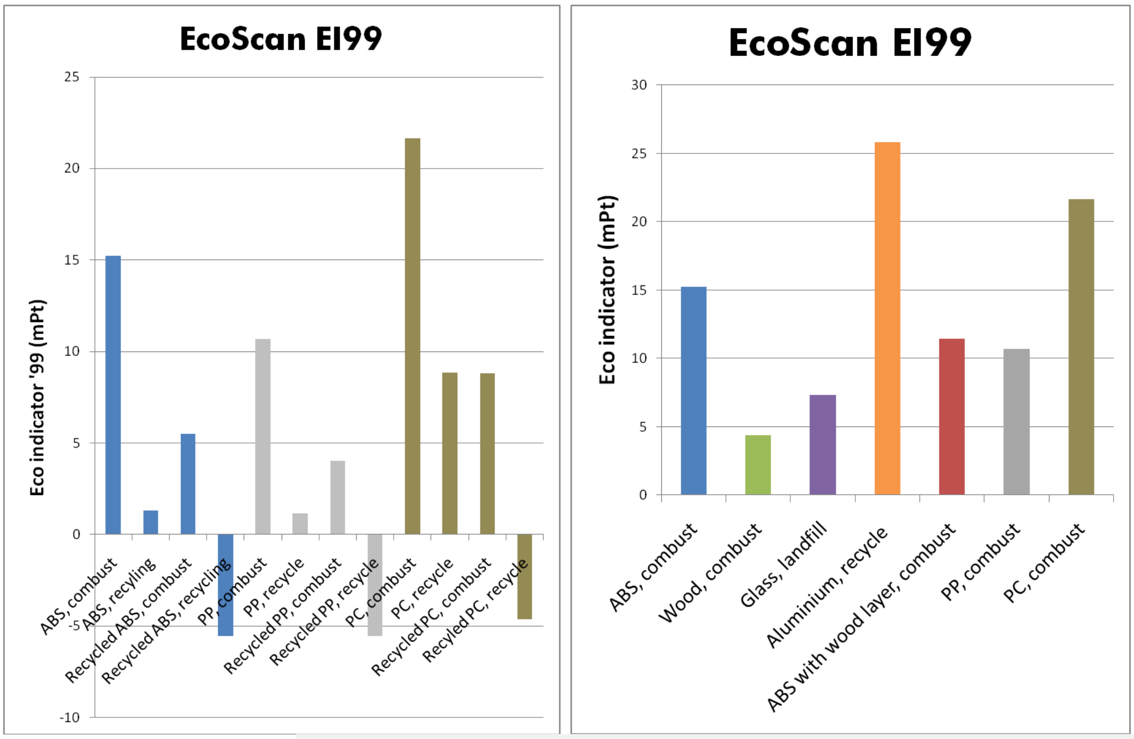


Figure 5.11 | 5.12: Charts of values from EcoScan Eco indicator '99

Looking at figure 5.11 the trend in recycling materials for PP and ABS is the same, PC is almost the same. The values for incineration and recycling as a disposal scenario in EcoScan are the same for all materials. Virgin PC has a higher impact than PP and ABS, so when the values for plastic recycling are subtracted of this will have a somewhat other result. Only looking at the virgin materials in figure 5.12, shows the same order of materials as the Granta CES Selector gives when looking at eco indicator per volume of material.

In Appendix 3 some additional graphs are shown. Graph 3a shows the diversion of the eco indicator values on material, production and disposal. The graph shows that production and disposal do not have a big impact compared to the chosen material itself, except for the recycling scenarios. When recycling a material the disposal has a big negative influence on the eco indicator measures, which means that the impact of the material scenario will be significantly less. The graph also shows that the recycling scenario of recycled aluminium is less negative as the recycling of virgin aluminium. These values are available in the PES2007 database. For recycling plastics there is only one value for recycling. The same value is distracted from the virgin plastic as from the recycled plastic. This will result in negative values for the scenarios in which recycled plastics will be recycled. The values for recycling recycled plastics are probably lower than the values for recycling virgin plastics, the same as with aluminium. This is the same for the next paragraph with the CO2 results of EcoScan.

Graph 3b in Appendix 3 shows the diversion of the wood with lacquer scenario. This graph shows that the influence of the lacquer is 19% of the total environmental impact. The wood has the biggest influence. Graph 3c shows two graphs of glass with different disposal scenarios. Because Eco Audit is not able to calculate the incineration of glass, in all graph the disposal scenario used is landfill. The graph shows that this doesn't make a big difference when looking at the eco indicator values.

5.7 EcoScan results on CO2

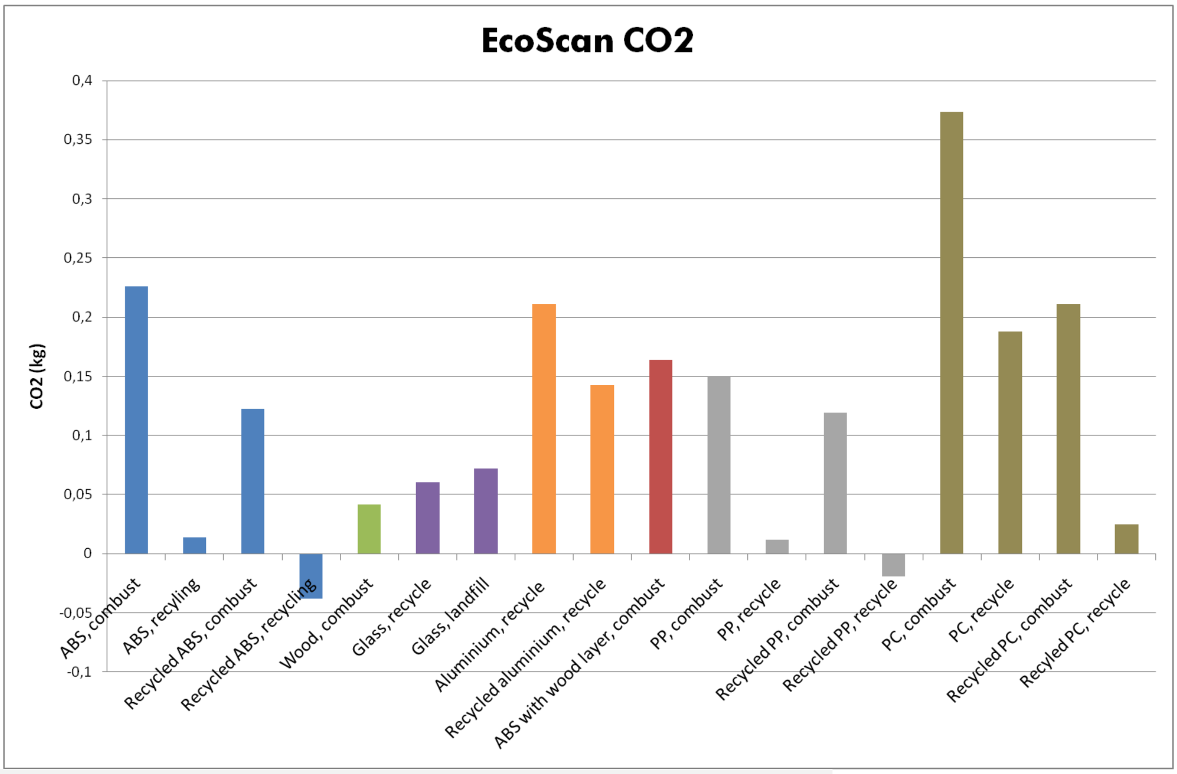


Figure 5.13: Chart of values from EcoScan CO2

Note

l. To calculate recycled ABS 30% of the CO^2 measure of normal ABS is used. *
m. To calculate recycled PP 30% of the CO^2 measure of normal PP is used. *
n. To calculate recycled PC 30% of the CO^2 measure of normal PC is used. *
o. The wood production process in sawing, no extra production process is added in EcoScan. There are no values for solid wood pressing.
p. For the lacquer on the wood, the value for lacquer on plastic is used. There is no value for lacquer on wood, only on metal and plastic. Lacquer on plastic is worse than on metal, therefore plastic is chosen.
q. The PES2007 database is used for the CO2 values. Except for the recycled plastics.

* Same percentage as used for eco indicator.

In figure 5.13 a chart is shown of the CO2 footprint of the material scenarios. The results are calculated in EcoScan. The values for recycling recycled PP and ABS are negative. This has the same reason as the negative values for the eco indicator from EcoScan. Recycling recycled PC has no negative value. Probably this is the result of the high value of virgin PC. When recycling the material a standard value of recycling plastics is subtracted. For PP and ABS this results in a negative value. For PC the value will become significantly lower, but not negative. Remarkable is the CO2 footprint of aluminium. The eco indicator of the aluminium is very high, but the CO2 footprint is compared to the other materials average.

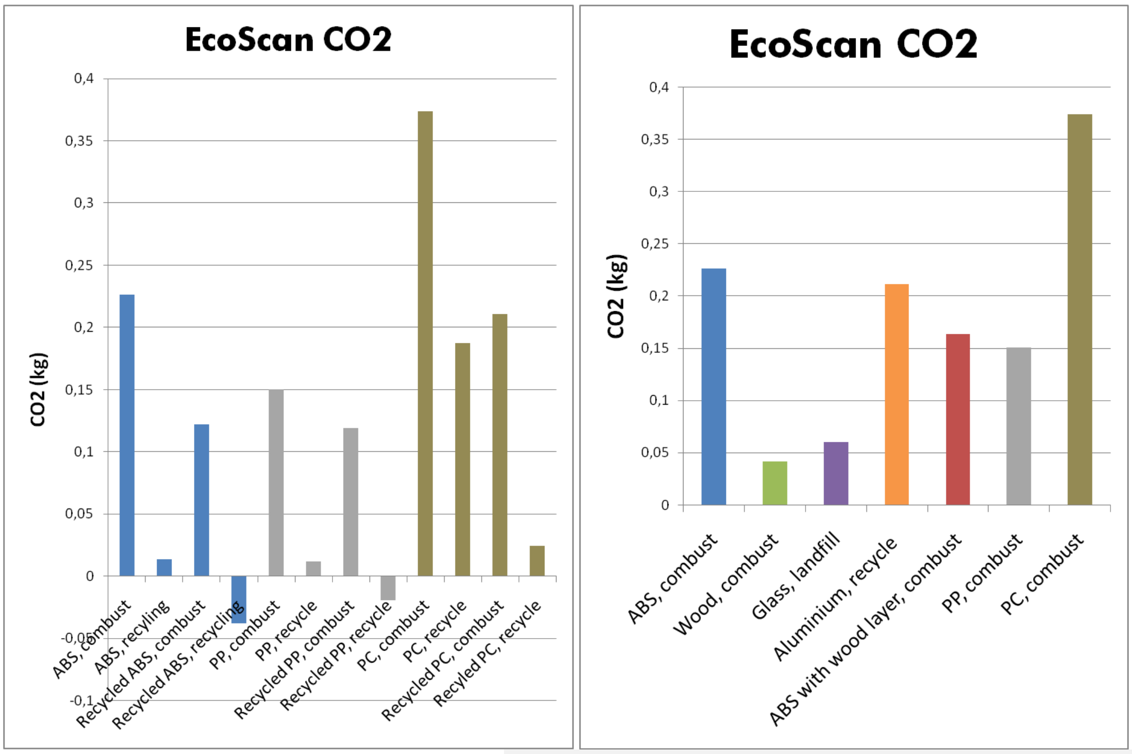


Figure 5.14 | 5.15: Charts of values from EcoScan CO2

In figure 5.14 the CO2 footprint of all plastic scenarios is shown. The trend in the PP and ABS values is the same. For PC the values vary, this is the result of the high value of virgin PC and the standard plastic values for recycling. The CO2 footprint in general is the lowest for PP; the second best is ABS. The worse plastic is PC. Figure 5.15 shows the CO2 footprint of all virgin materials. The order is almost the same as the results of the eco indicator results. Only aluminium has switched from the worse material to third in order.

5.8 Eco audit results on energy

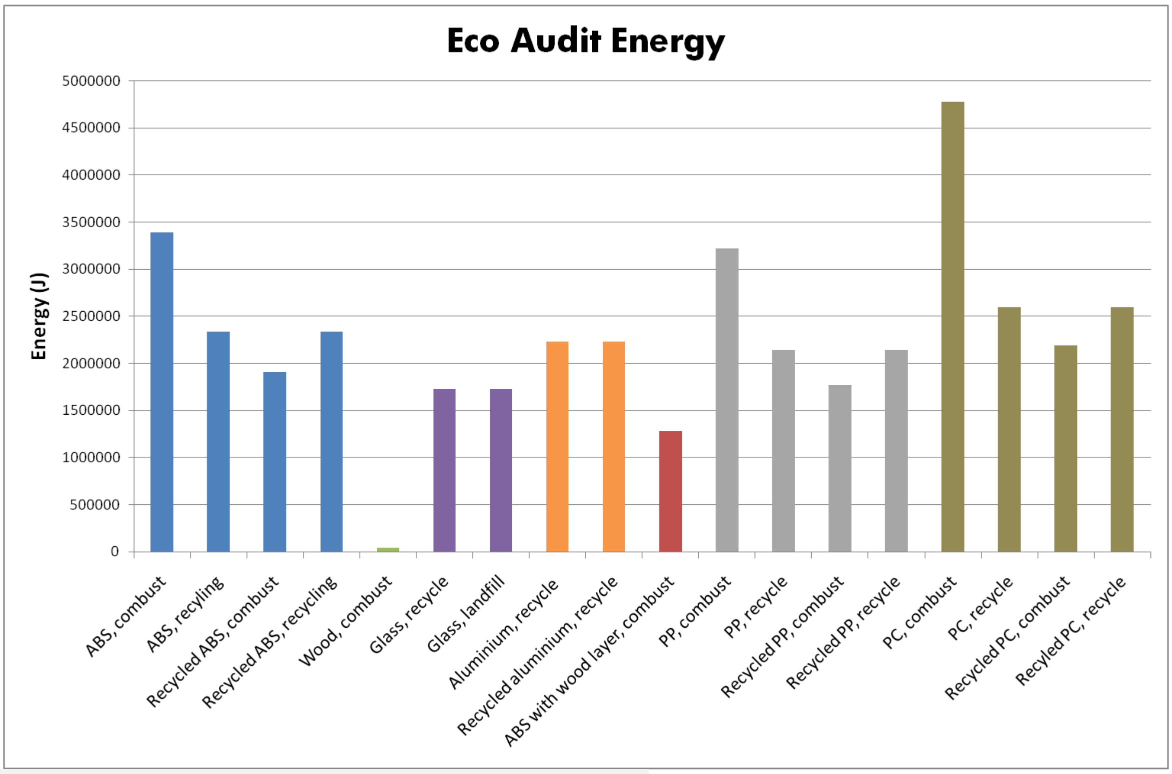


Figure 5.16: Chart of values from Eco Audit energy

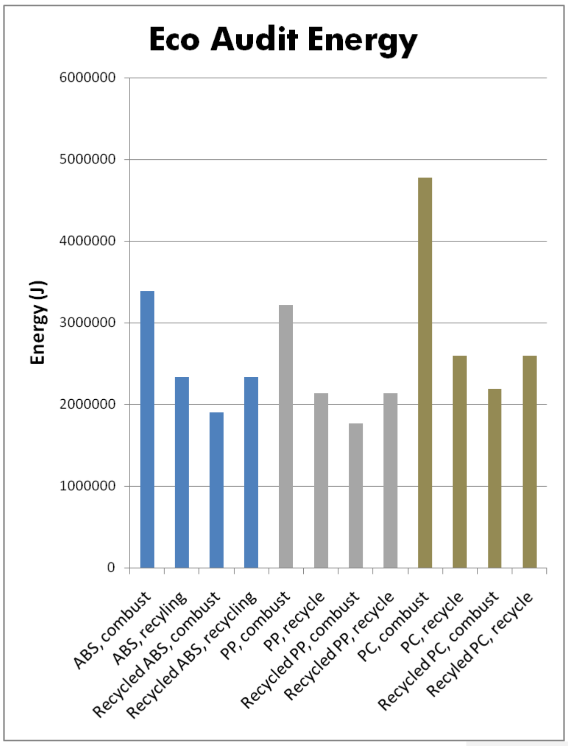
Note

r. For scenario 2, the production process used is assembly and construction. There are no other production processes available.
s. For scenario 2, no lacquer is applied. There is no value for lacquer in the database.
t. There is used a typical percentage of recycled glass for scenario 3a and 3b.
u. For the values on aluminium an average aluminium type is used: A 356 T6.
v. For the recycled aluminium a typical percentage of recycled aluminium is used.

The graph in figure 5.16 shows the energy consumption of the different scenarios. The energy consumption is calculated for the material, production and disposal. The graph is made of the output of Eco Audit. Most material scenarios are better than the current scenario, only using virgin PC and incinerate it is worse. The values for recycled materials that will be recycled and the virgin materials that will be recycled are the same according to the software calculation. There should be looked more closely to this occurrence and the calculation method behind it.

Note nr. s states that no lacquer is applied to the wood, because this is not possible in Eco Audit. In Appendix 3b the eco indicator values for wood are divided. This shows that the lacquer only accounts for 19% of the environmental impact. In the graphs Eco Audit graphs, the impact of wood is significantly low. The assumption can be made that even with the lacquer applied the energy consumption and CO2 production, in the next paragraph, of this scenarios is still the lowest.

Interesting is the result for wood. Even if the wood is combusted it is still better recycled plastics. In the EcoScan results wood also has a good score. In EcoScan recycling plastics and recycling glass is better, than using wood.



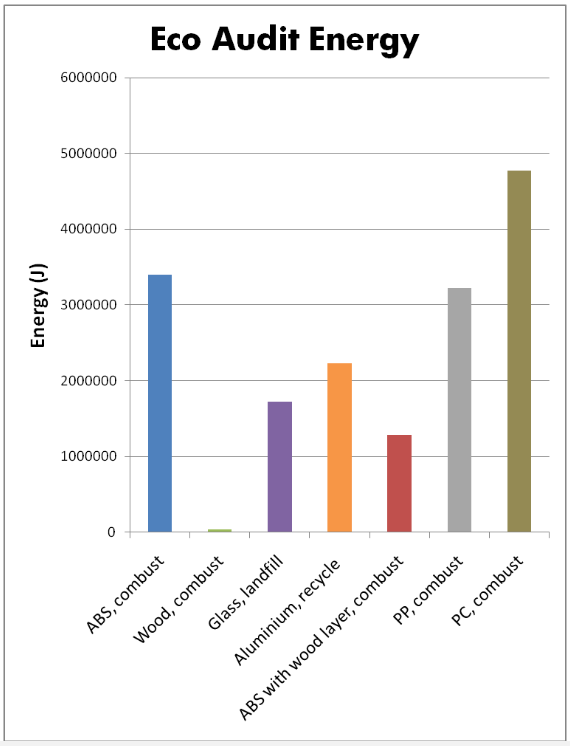


Figure 5.17 | 5.18: Charts of values from Eco Audit energy

In figure 5.17 the results for only plastics is shown. The trend in these materials scenarios is for all three plastics the same. The recycling scenarios are all better than the virgin materials that will be incinerated. In figure 5.18 the results for all virgin materials are graphed. As can be seen, the order for virgin materials is almost the same as the results for the Granta CES Selector eco indicator and embodied energy chart per volume. The change is aluminium, which has switched from the worse material to third best.

5.9 Eco audit results on CO2

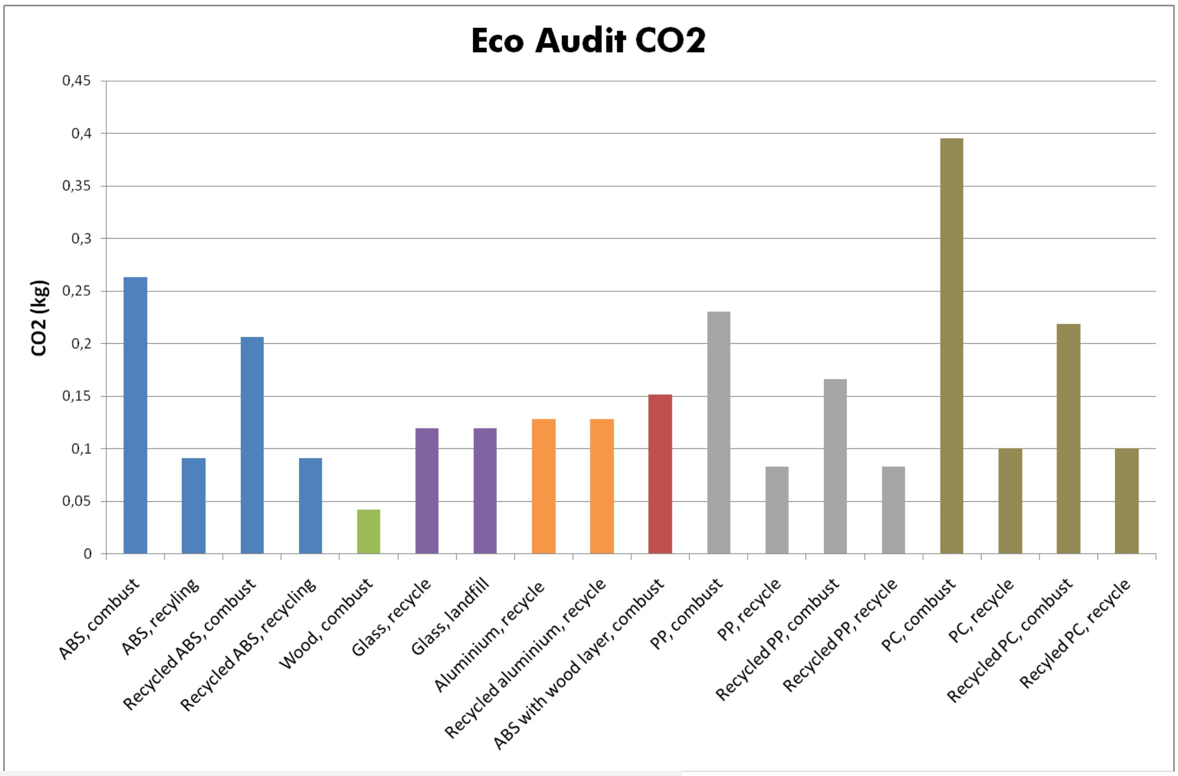
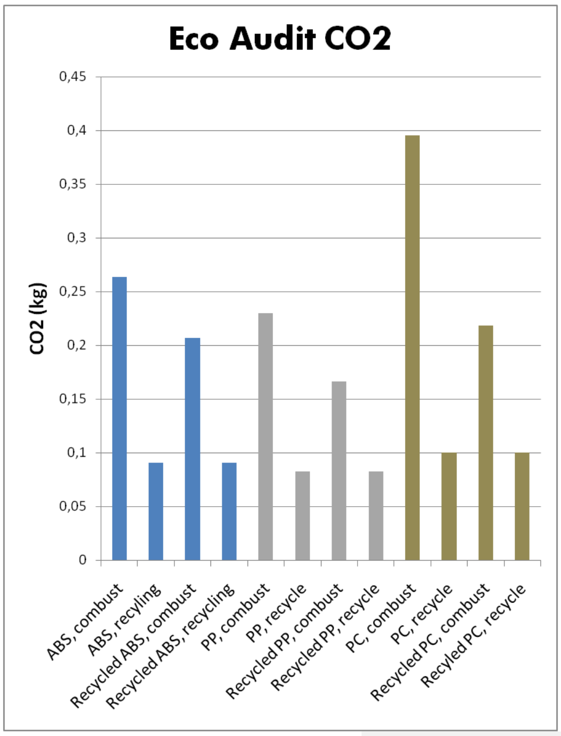


Figure 5.19: Chart of values from Eco Audit CO2

Note

w. For scenario 2, the production process used is assembly and construction. There are no other production processes available.
x. For scenario 2, no lacquer is applied. There is no value for lacquer in the database.
y. There is used a typical percentage of recycled glass for scenario 3a and 3b.
z. For the values on aluminium an average aluminium type is used: A 356 T6.
aa. For the recycled aluminium a typical percentage of recycled aluminium is used.

In figure 5.19 the results Eco Audit on CO2 footprint of the different scenarios is shown. The results are calculated for the materials, production and disposal CO2 emissions. The CO2 footprint of all scenarios, instead of PC incineration, is better than the current SENSEO lid cover. Just as in the energy graph of Eco Audit results of recycling virgin material or recycled materials are the same. This probably has the same cause as in the energy graphs and there should be looked at the calculations made for these results. Remarkable is the CO2 footprint of recycled plastics. The CO2 footprint of the recycled plastics is low, and beside wood, the best choices.



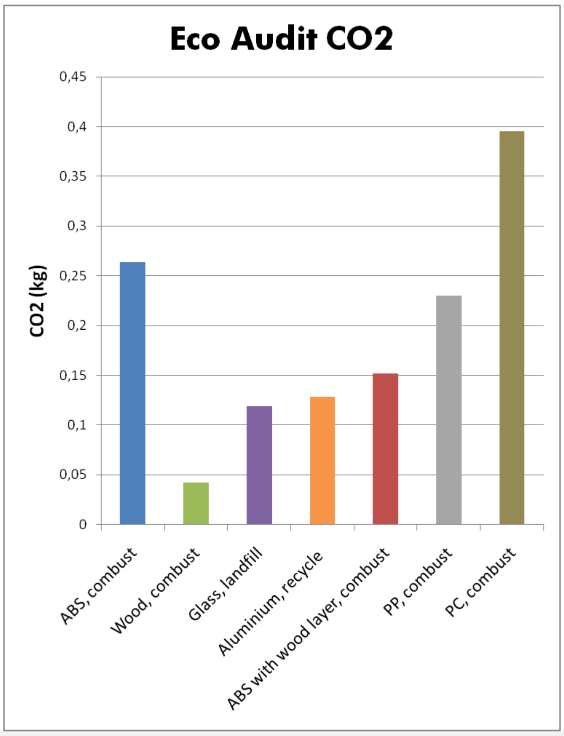


Figure 5.20 | 5.21: Charts of values from Eco Audit CO2

Figure 5.20 represents the CO2 footprint of all plastic scenarios. The trend in these material scenarios is for all three plastics the same. The order of the plastics is the same as in the other results for plastic of EcoScan and Eco Audit, figure 5.11 and 5.14. In figure 5.21 all scenarios with virgin materials are shown. The order of the materials is somewhat different than in the results of EcoScan. The change is aluminium, which has switched from the worse material to third best.

5.10 Comparison of results

The results of the life cycle analysis with EcoScan and Eco Audit and the results of the Granta CES Selector will be compared to get an idea of the differences between the results.

Granta CES Selector

For virgin materials the eco indicator per volume graphs of the Granta CES Selector has the same results of the EcoScan values for virgin materials. Recycled plastics are not available in the Granta CES Selector so the results are not complete when all the materials need to be compared.

Percentages

Figure 5.22 shows a graph of the percentages of the different materials scenarios. The percentages are based on the current SENSEO lid cover is 100%. The graph shows that the values do not comply with each other. That was to be expected, because the variables that are measures are different and the methods of the calculations are different as well. In the graph there can be seen that even the trends of the different results are different. For instance the results for recycling recycled plastics. The approach of EcoScan regarding to recycling plastics is different to the approach of Eco Audit, this results in different results for these scenarios.

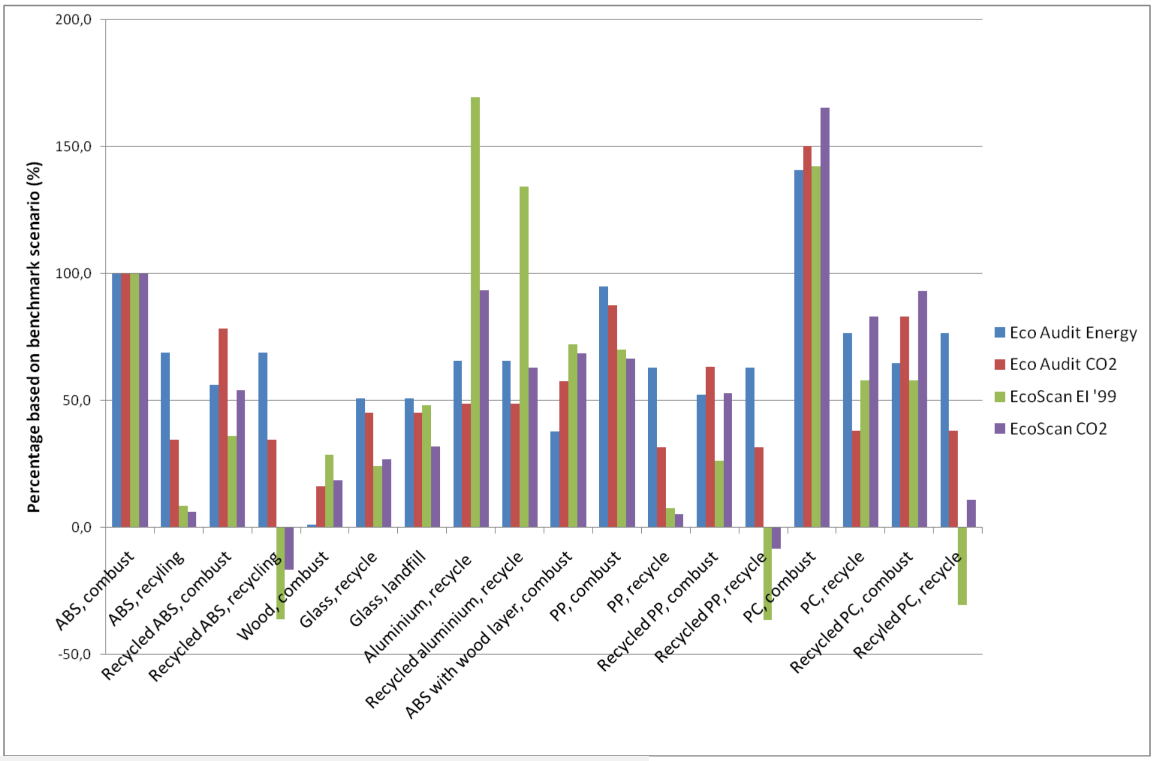


Figure 5.22: Percentages chart

Note
bb. Percentages based on scenario 0 = 100%.

In Appendix 4 a graph is shown of the CO2 footprint calculated in EcoScan and in Eco Audit in the same graph. This graph shows that both programs do not present the same results when measuring the same value.

5.11 Conclusions

Based on the graphs made in this case study and the sustainable materials theory, conclusion can be drawn for making a sustainable SENSEO. These conclusions are shaped in a list of guidelines for sustainable material choices in the SENSEO. These guidelines will be used by developing a general strategy for sustainable material choices. These guidelines are:

1. Use as less different materials as possible. At the end of life there will be less waste streams needed to recycle the materials.
2. Use recycled materials. The best would be closed loop materials, because there will be taken care of the old Philips appliances. Using recycled materials is a good first step.
3. When looking at virgin materials as a substitute for plastics, use a fast growing wood or glass.
4. Make sure no toxic substances are used in the materials.
5. Think about the product, and work together with ARC, design, marketing, etc. The product needs to be sustainable, but also needs to be sold. Think about the benefits to the customer, for instance costs, appearance, attractiveness, usability, etc. A product that is made, but not used is not sustainable at all, it needs to fulfil a function.
6. Always keep the product life cycle in mind. Think about the changes in the product life cycle due to the material change:
   - **Weight of product:** If the part gets heavier by using a different material this can be a negative influence. If it gets lighter there is no problem.
   - **Transport:** Make sure the new material doesn't need significantly more transporting.
   - **Processing:** Other processing can have another impact on the environment. In general the processing doesn't influence the overall sustainability that much.
   - **Use:** Make sure there are no extra energy losses due to the material change. This may for instance happen in a water container when water is boiled.
   - **Volume:** For engineering more or less material is needed for the function of the part due to the material change. For instance because of the stiffness of the material. The weight of the part will change.
   - **Disposal possibilities:** Not all materials can be recycled, some need to be incinerated. It also needs to be possible to disassemble the product after use, for recycling the materials.

In the results of the life cycle analysis can be seen that the materials have the biggest impact compared to production and disposal. Only in recycling the disposal stage has a big impact as well. To use the Granta CES Selector which only compares the materials on material level will give a good representation.

In the next chapter the general use of the Granta CES Selector for Philips will be discussed for making sustainable material choices. The way the Granta CES Selector will be applied in this method is based on this case study and its conclusions.

6. Philips sustainable material selection with Granta CES selector

The main goal of the assignment was to implement the Granta CES Selector within Philips. In this chapter the use of the Granta CES Selector within Philips will be discussed. The main topics are how to use the software program, how to make sustainable material choices, fitting the Philips strategy, the added value of the software program and the shortcomings.

6.1 How to use the Granta CES Selector in Philips sustainable projects

The values coming from EcoScan and Eco Audit differ. This is to be expected since the calculation methods and types of results are different. For Philips the EcoScan values are important for validating the sustainability of the product and getting the Simple Switch logo. The order of the material scenarios on sustainability of the Granta CES Selector eco indicator per volume corresponds with the order of scenarios calculating the EcoScan eco indicator value.

The recommendation is to use the Granta CES Selector at the beginning of the product development process, as soon as material choices are a topic. Looking at the sustainability of the materials beforehand will prevent unpleasant surprises in later stages of the project. The possible choices can be plotted in a graph of eco indicator per volume, which will give an impression of the sustainability of the different materials. Making such a graph takes only a couple of minutes, so this is a very efficient way to get an overview. Besides the information that is available in the Granta CES Selector, think about recycling the materials. Recycled plastics cannot be plotted in the graph, but can be a good option as sustainable material, keep this in mind when working with the Granta CES Selector. In later stages of the product development process EcoScan can be used to check the sustainability of the whole product. To use EcoScan a good image of the product and a bill of materials is needed. Therefore this can only be done in later stages of the project. It also takes some time to fill in the data that is needed in EcoScan. Summarizing, the Granta CES Selector can be used in the beginning of the project and EcoScan can be used in later stages. This way the software programs will work together very efficiently. In figure 6.1 the use of the software tools is drawn in the Philips product development strategy. The overlap area depends on the project that is being worked on.

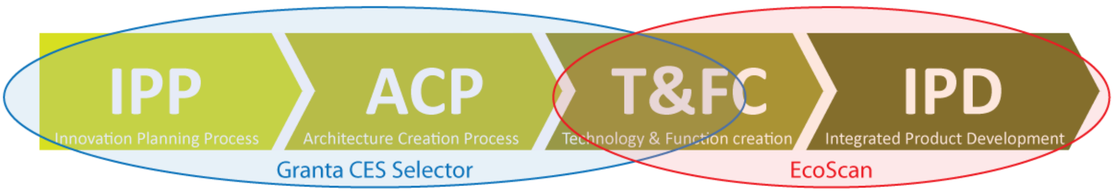


Figure 6.1: The use of software tools within Philips product development

In the strategy of using Granta CES Selector within Philips the Eco Audit is not used. The reason for this is that EcoScan and Eco Audit both do a life cycle analysis. The Eco Audit is somewhat faster to use and the output is different. But EcoScan has to be used at some milestones in the product development anyway. The most efficient way to make sustainable material choices is to make the choices in the beginning of the production process with the CES Selector when the design choices are still fluid and then verify the sustainability of the product later with EcoScan. The only added value of using the Eco Audit is the ability to calculate with recycled materials. Since EcoScan needs to be used, it would be better to improve the database used in EcoScan.

6.2 Who will use the Granta CES Selector

The technical material selection within a Philips project team is done by the project engineers and function development, see figure 1.5. The Granta CES Selector is based on the technical and environmental properties of the materials. The project engineers and function development can use the software program. The information that is needed for some other functions or specifications can also be found in the Granta CES Selector, for instance RoHS grades, costs and suppliers.

6.3 How to make sustainable material choices

Making sustainable material choices is a process that will occur during a product development project. Making a sustainable material choice includes more than only choosing the material itself. In figure 6.2 a step-by-step plan is presented for sustainable material selection. The steps will be explained separately. This strategy is based on the functions of a product engineer or function developer and can be included in the standard engineering work. These steps represent the basics underlying sustainability. When working through the step-by-step plan the amount of materials you can choose will decrease. Some steps can be interchangeable, but it is recommended to follow this order.

Figure 6.2: Step-by-step plan for sustainable material selection

Think about the future

When designing a product, think about the disposal of the product beforehand. Use as less different materials as possible. This will save energy at the end of the product life, by reducing the waste streams for recycling. Think about the separation of the materials at the end of the product life, when engineering the product. Separation of different materials, especially when the material properties are similar, can be difficult and will increase the price and decrease the quality of the recycled material. Use as pure materials as possible. Requirements on the material properties can be set. For instance: the material needs to be recyclable.

Make sustainable material choices

Think about the materials that will be used. Use recycled materials. The best would be closed loop materials, because there will be taken care of the old Philips appliances. Using recycled materials is a good first step. Think also about virgin materials that have a low environmental impact. With the Granta CES Selector the environmental impact of the different materials can easily be checked. When Granta CES Selector is used be sure you make graphs based on the eco indicator per volume of the materials. This will represent the function of the material. In a life cycle analysis on material, production and disposal the material phase itself will account for the biggest environmental impact compared to the production and disposal of the product. Recycling the material will have a big impact on the environmental impact disposal phase of the material. So the Granta CES Selector graphs of eco indicator per volume of material will give a good representation of the environmental impact of the material, except for recycling scenarios.

The normal material requirements used in engineering can be included in this stage. Materials that do not meet the requirements can be excluded. Take two or three materials that are suitable for the design and sustainable to examine further. Taking a few options will prevent that there are no materials left in the end when all steps are taken.

Check for toxic substances

Make sure no toxic substances are inside the material. The legislation and the regulated substances list exclude a lot of materials with toxic substances, but this can be more expended. The preferred materials list will present trustful and recoverable materials. The trustfulness will include the absence of toxics. Think also about other 'bad' substances like PVC, BFR, etc. Even though they are not included in the regulated substances list, it will be good to exclude as much bad substances as possible.

Check the product life cycle

Think about the changes you have to make when choosing a different material. These choices can affect the overall sustainability of the product life cycle. It is not necessary to do a life cycle analysis for all possible materials in EcoScan. Think about the possible effects of the choices that are made. Use this checklist:

- **Weight of product:** If the part gets heavier by using a different material this can be a negative influence. If it gets lighter there is no problem.
- **Transport:** Make sure the new material doesn't need significantly more transporting.
- **Processing:** Other processing can have another impact on the environment. In general the processing doesn't influence the overall sustainability that much.
- **Use:** Make sure there are no extra energy losses due to the material change. This may for instance happen in a water container when water is boiled.
- **Volume:** For engineering more or less material is needed for the function of the part due to the material change. For instance because of the stiffness of the material. The weight of the part will change.
- **Disposal possibilities:** Not all materials can be recycled, some need to be incinerated. It also needs to be possible to disassemble the product after use, for recycling the materials.

The overall sustainability of the product throughout the whole life cycle needs to be good. When it is not clear if the change has a bad influence, a quick life cycle analysis can be done. This can be done with scenarios in EcoScan. Make sure the scenarios are clear. Define the material, the production method and the disposal of the product. Also make sure the weights of the materials are clear. If the volume of the part is not clear jet, take a standard volume and calculate the weight with the density of the different materials. The densities can be found in the datasheets of the Granta CES Selector, see Appendix 7. If there is given a range of densities, take the average. When using EcoScan some assumptions need to be made. This is no problem: making assumptions is always better than doing nothing. Make sure the assumptions are recorded clearly.

When working with material life cycles, look at least at the material, production and disposal. These phases all have influence on the sustainability of the material that will be measured. Sometimes only the production energy or CO2 production is measured, this will give a distorted image of the sustainability. The production energy of a material can be higher than another, but the overall sustainability is the most important. This is also what will be measured in EcoScan.

Discuss with Design, Marketing and ARC

The product needs to be sustainable, but also needs to be sold. Think about the benefits to the customer, for instance costs, appearance, attractiveness, usability, etc. A product that is made, but not used is not sustainable at all, it needs to fulfil a function. The research of these functions can influence the possible material choices. When the consumer doesn't like a specific material, even if it is sustainable, don't use it.

Some of the steps presented in the step-by-step plan may contradict. When making material choices think clearly and make well-founded decisions. If in the end there are no materials left, start at the beginning of the step-by-step plan and adjust the requirements.

6.4 Fitting in the Philips strategy

As discussed earlier the Granta CES Selector will fit the Philips product development strategy. Some legislation can be checked with the software programs as well, for instance food approval and RoHS. This makes it easier to check if materials from different suppliers can be used for the parts of Philips products and to exclude materials that are not suitable. Because the program is easy to use and gives some overview fast, it fits the overall sense and simplicity strategy of Philips. Not only for the use in sustainable material selection, but in general material selection as well.

Some of the Green Focus Areas can be checked with the Granta CES Selector. The hazardous substances can be checked with the toxicity and RoHS properties of the materials in the database. The recycling and disposal possibilities can also be found in the datasheets and can be set as a limit.

6.5 Added value Granta CES Selector

The added value of the Granta CES Selector for Philips is that it will give an overview on the sustainability of materials fast and easy. This overview is normally hard to get and will take a long time. The software program will give the opportunity to make sustainable material choices in the earlier stages of the product development process, when the design decisions are still fluid. This will make it easier to make sustainable choices, because the changes won't have to be made in later stages, where the construction of parts may need to be changed. Another added value of the software program is the link to the engineering properties. This can be done with trade off charts or with indices. In appendix 7 this will be explained.

6.6 Shortcomings

The Granta CES Selector has some shortcomings when working with the software program for sustainable materials selection within a Philips product development project. These shortcoming can be worked on, and probably some are not present in the newer versions of the Granta CES Selector.

For the eco indicator values the ’95 method is used. Within Philips the ’99 method is used for EcoScan and the weighting factors are adjusted to the Philips strategy. The eco indicator ’95 and ’99 are not comparable, because they are calculated with different impact assessment methods. For comparing materials in the Granta CES Selector the eco indicator ’95 will give similar results as EcoScan, so it can be used. It would be better if the ’99 method or recipe was used. Recipe is the future method for Philips. For now there can be worked with the eco indicator ’95 values. In the future versions of the Granta CES Selector the eco indicator ’99 will be used.

In the Granta CES Selector it is not possible to compare virgin materials with recycled materials. The software program can calculate with recycled plastics in the Eco Audit. It would be convenient if that information would be transformed into the material database. That way for instance the embodied energy of virgin PP could be compared to the embodied energy of recycled PP. This would complete the comparison of materials and the overview, when choosing a sustainable material.

In appendix 5 the knowledge transfer on using the Granta CES Selector and Sustainable materials for Philips is explained. In appendix 6 to 8 the corresponding sheets can be found.

Conclusion

The goal of the assignment was to find a way of implementing the Granta CES Selector in the IDA community for sustainable material choices. Therefore information of the Philips product development process, the Philips sustainability procedures was needed and more familiarity with the software program was needed. As a case study for selecting sustainable materials the SENSEO was used.

With the findings of this research a general strategy for selecting sustainable materials for Philips appliances is made. This strategy is designed in a step-by-step plan, the product engineers and function developers could use for making sustainable material choices. The step-by-step plan includes the use of the Granta CES Selector and when more information is needed the use of the EcoScan with material scenarios.

The conclusion is drawn that the Granta CES Selector is suitable for use in the earlier stages of the Philips product development process. Besides the use of the software program other things are important as well in sustainable material choices. For instance recycling scenarios should be considered. When choosing a sustainable material it is still important to reflect on the choice. The overall sustainability of the product life cycle needs to be good. If the material choice influences the product life cycle in a negative way, the material choice is not sensible. In the step-by-step plan a checklist is included for the changes in the product life cycle that might influence the overall sustainability.

In sustainable material choices Philips is already on the right track by using as few different materials as possible. Using PP as a first choice is a good starting point, especially when there will be looked at the recycling of the materials. In some cases less different types of materials can be used in a product. Especially in case of the usage of ABS and PC, in some parts these materials are only chosen because of their looks. Though when looking at sustainable materials for Philips appliances it is important to keep having contact with Design, Marketing and ARC. The product needs to be attractive. When a product is made, but not used, it is not sustainable at all.

Recommendations

It is not easy to make sustainable material choices, because there are many things there should be looked at. For making sustainable materials for Philips appliances follow the step-by-step plan to make well-founded discussions. The step-by-step plan includes the most important information that is needed to make sustainable material choices.

To make the Granta CES Selector more usable than it already is contact Granta to update the possibilities of the software program. The most important shortcomings of the software program are described in Paragraph 6.6. For the use of the Granta CES Selector for sustainable material choices within Philips, the comparison of recycled plastics to virgin materials would be helpful.

Update the database used in EcoScan and include recycled plastics and the values for recycling recycled plastics. For updating the database information from suppliers is needed.

References

Ashby, M. F. (2009). *Materials and the Environment: Eco-informed Material Choice*. Oxford: Elsevier Inc.

Ashby, M. F., Coulter, P., Ball, N., & Bream, C. (2009). *The Granta Eco Audit Tool - A White Paper*. Cambridge: Granta Design Ltd.

Ashby, M. F., Miller, A., Rutter, F., Seymour, C., & Wegst, U. G. K. (2005). *The CES Eco Selector - Background Reading*. Cambridge: Granta Design Ltd.

Ashby, M. F., Shercliff, H., & Cebon, D. (2007). *Materials: engineering, science, processing and design*. Oxford: Elsevier Inc.

Braungart, M., & McDonough, W. (2007). *Cradle to Cradle: afval is voedsel*. Heeswijk: Search Knowledge B.V.

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emmisions - a strategy for eco-effective product and system design. *Journal of Cleaner Production, Elsevier, 15*, 1337-1348.

Goedkoop, M., Demmers, M., & Collignon, M. (1996). *The Eco-indicator '95: Manual for designers*.

GrantaDesign. (2009). CES Selector: Granta Design Limited 1991-2009.

Luttropp, C., & Lagerstedt, J. (2006). EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development *Journal of Cleaner Production, Elsevier, 14*, 1396-1408.

Ministery of Housing, S. P. a. t. E. (2000). Eco-indicator 99 Manual for Designers: A damage oriented method for Life Cycle Impact Assessment.

Philips. (2010). Internal Webpages and Documents. Retrieved during assignment period at Philips, 2010

PReConsultants. (2010a). Database Ecoinvent 2.2 from PRe Consultants:

PReConsultants. (2010b). Simapro 7.2.3: PRe Consultants Bv.

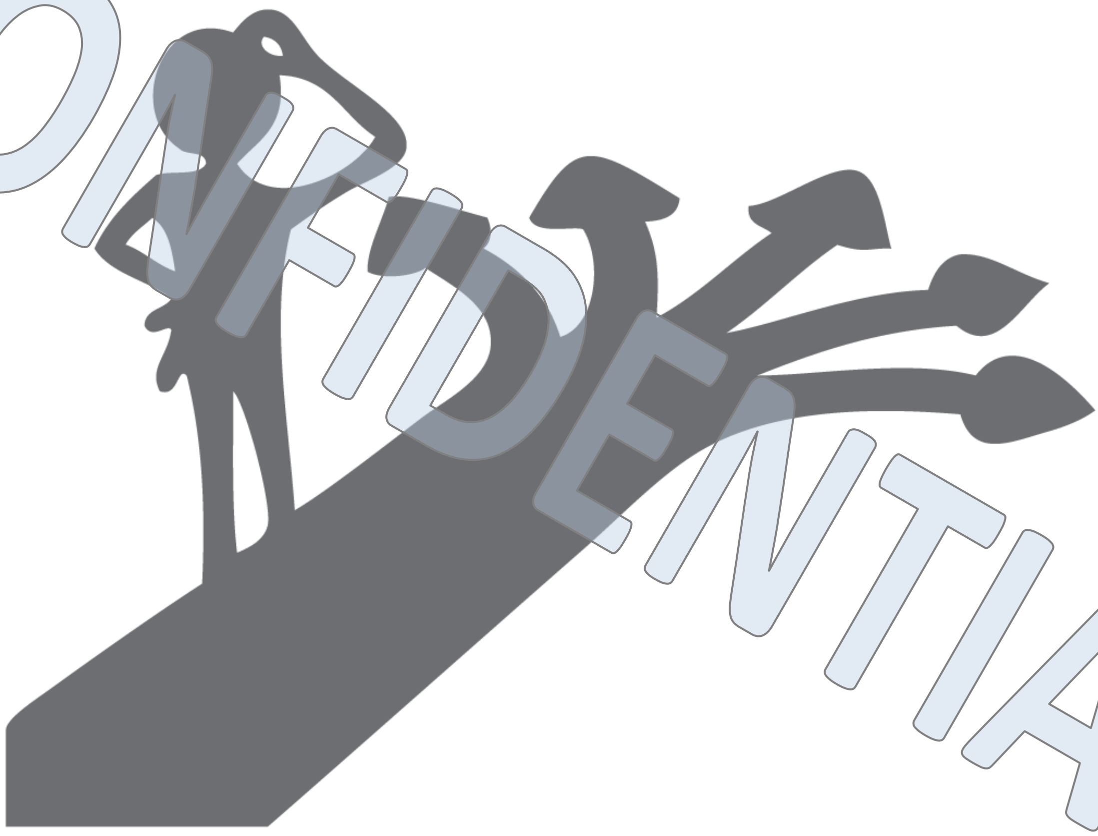
TNO. (2004). EcoScan life 3.1: TNO 2004.

Toxopeus, M. (2010). Sheets ketenbeheer (114503): University of Twente.

2010

PHILIPS & UNIVERSITY OF TWENTE

Marieke Brouwer
Industrial Design Engineering



SUSTAINABLE MATERIAL SELECTION

APPENDICES

Table of contents

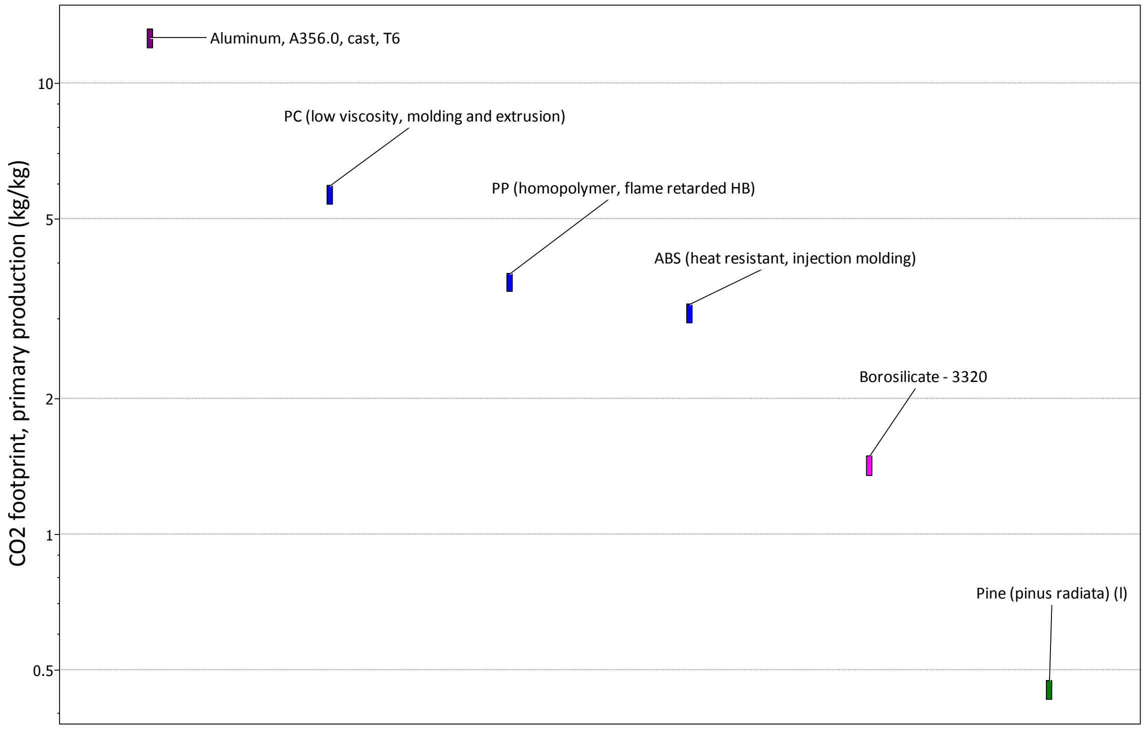
1. Definitions and abbreviations

ABS	Acrylonitril Butadieen Stryreen, thermoplastic.
Acidification	Process in which the PH value of an ecosystem deceases.
ACP	Architecture creation process. Philips project in which the feasibility of the project will be checked.
BFR	Brominated flame retardant. Material substances that have a restraining influence on the combustion of the materials. These substances are used for safety reasons.
BOM	Bill of materials, list of parts of a product specifying the used materials and master batches. (Master batches give the colour to the material).
Carcinogen	Any substance, radionuclide or radiation that can cause cancer.
Climate Change	The way the world's weather is changing.
CO2 footprint	The amount of CO2 that a material, product, etc produces during the life cycle.
Combust	Burning a product or material completely. In this context the energy produced during the burning will be collected and used again.
Downcycling	Reusing the materials in a new product with less quality as the previous.
Eco indicator	A measure of sustainability, taking various environmental impact categories into account.
Eco-Audit	Tool of the Granta CES selector in which the environmental impact of a product during its life can be measured on energy and CO2 production.
EcoScan	Currently used life cycle analysis software within the Philips IDA teams. Used for validation of Sustainable products.
Ecotoxicity	The potential for biological, chemical physical stressors to affect ecosytems.
Embodied energy	Energy per unit mass consumed in making a material from its ores and feedstock.
EPEA	Environmental Protection and Encouragement Agency. Companies of Micheal Braungart helping businesses adapt the Cradle to Cradle strategy and doing hazard analysis on materials.
Eutrophication	The increase in the concentration of chemical nutrients in an ecosystem to an extent that increases the primary productivity of the ecosystem.

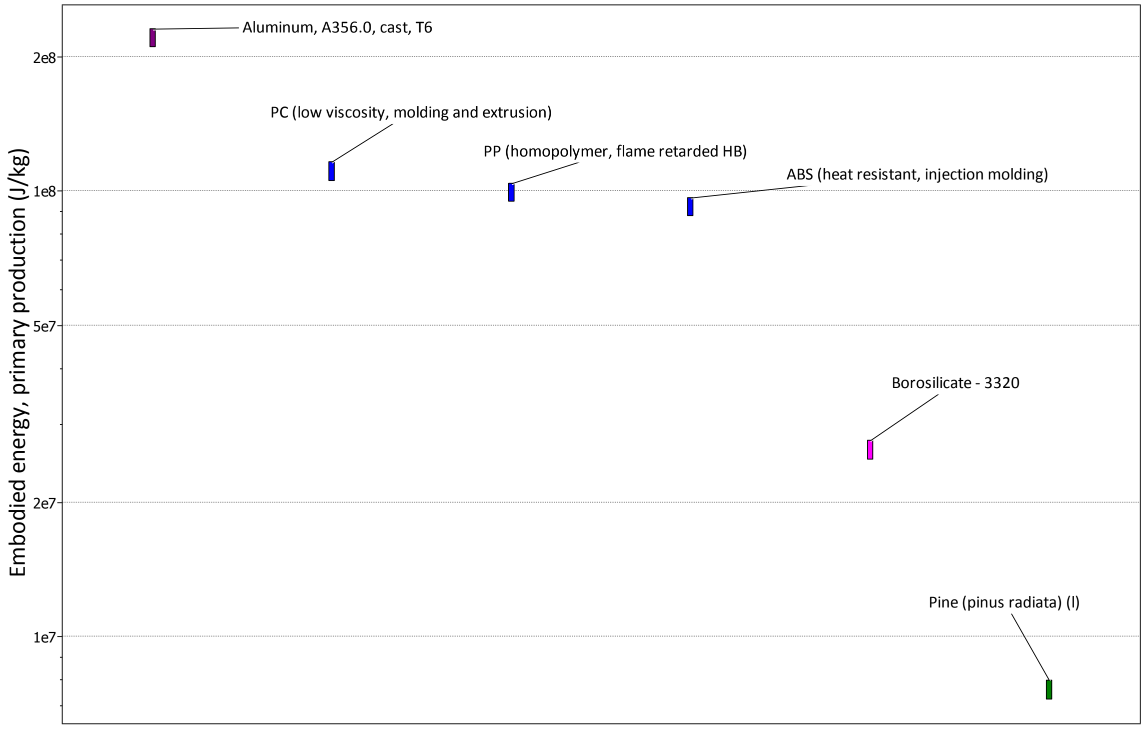
Fossil Fuels	Fuels such as gas, coal and oil, which were formed underground from plant and animal remains millions of years ago.
GER	Gross Energy Requirement, contains the summation of consumed energy throughout the life cycle and feedstock of a product or material.
GPW	Global Warming Potentials, for instance expressed in kg CO2 equivalents: 1 kg substance is able to absorb heat radiation with respect to 1 kg C02.
Granta CES selector	Software in with materials can be distinguished on their properties.
Greenhouse effect	An increase in the amount of carbon dioxide and other gases in the atmosphere which is believed to be the cause of a gradual warming of the surface of the Earth.
Heavy metals	Dense (= heavy in relation to its size) and usually poisonous metal, such as lead.
Human Toxicity	The potential for biological, chemical physical stressors to affect human health.
IDA	Innovation Domestic Appliances, part of the Philips Consumer Lifestyle Business.
Incinerate	Burning a product or material completely. In this context the energy produced during the burning will be collected and used again.
IPD	Integrated Product Development. Philips project in which the realization of the product takes place.
IPP	Innovation planning process.
Minerals	Valuable or useful chemical substances which are formed naturally in the ground.
Ozone layer depletion	Process in which the ozon layer decreases.
PA 66 (GF)	Polyamide (Nylon), thermoplastic.
PC	Polycarbonaat, thermoplastic .
Pesticides	A substance or mixture of substances, in this context mostly chemical, intended to prevent or destroying any pest. A pest is a organism that is harmful for humans.
PP	Polypropeen, thermoplastic.
PVC	Polyvinyl chloride, thermoplastic.
Radiation	A form of energy that comes from a nuclear reaction and that can be very

	dangerous to health.
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances, is an EU regulation on chemicals and their safe use.
Recycling	Reusing the materials in the next product. The quality of the material will be the same.
Respiratory inorganic	Substances that affect the breathing functions.
Respiratory organic	Substances that affect the breathing functions.
RoHS	EU directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment.
SharePoint	An internet database in which all documents for Philips are placed. There are different databases on different subjects.
Smog	Air pollution, especially in cities, that is caused by a mixture of smoke, gases and chemicals.
Sustainability	Environmentally friendliness of products and materials for the total lifecycle and beyond.
T&FC	Technical function development, Philips product development process in which the functions of the product are worked out and checked if they are feasible.
Upcycling	Reusing the materials in the next product. The quality of the material will be the higher.
Virgin plastic	Plastics that are made of oil (its feedstock) and do not have a recycled content.
WEEE	Waste Electrical and Electronic Equipment, EU directive that makes producers responsible for taking back and recycling electrical and electronic equipment.

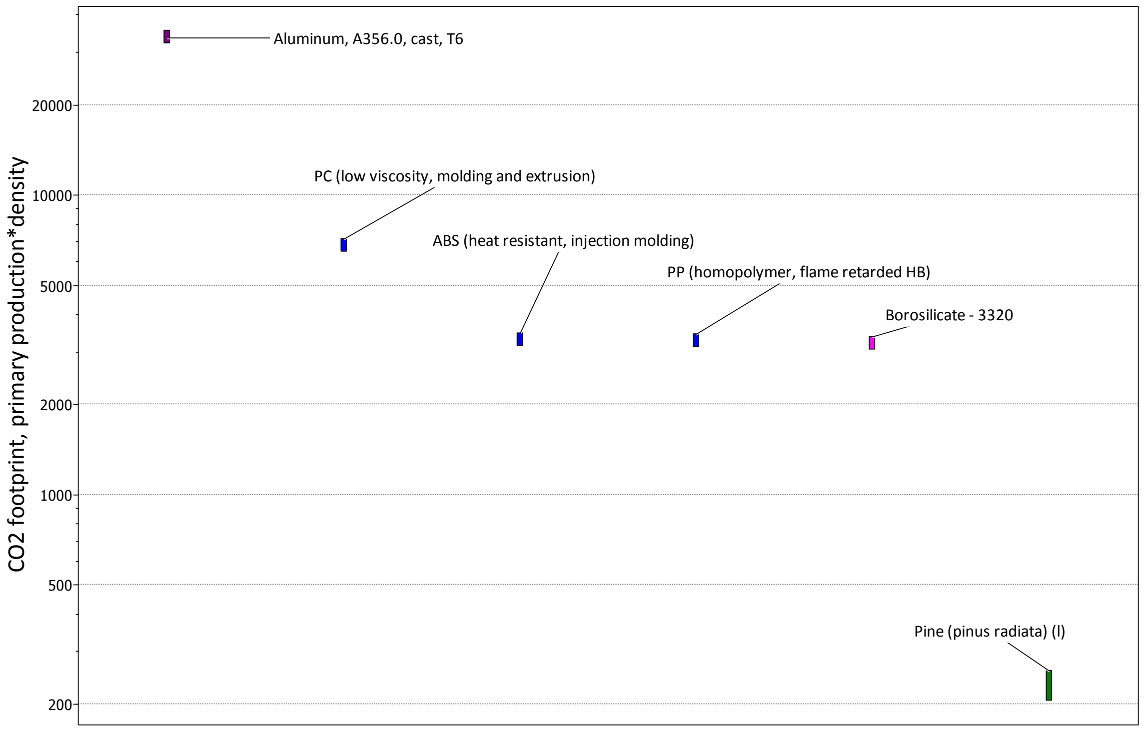
2. CES graphs

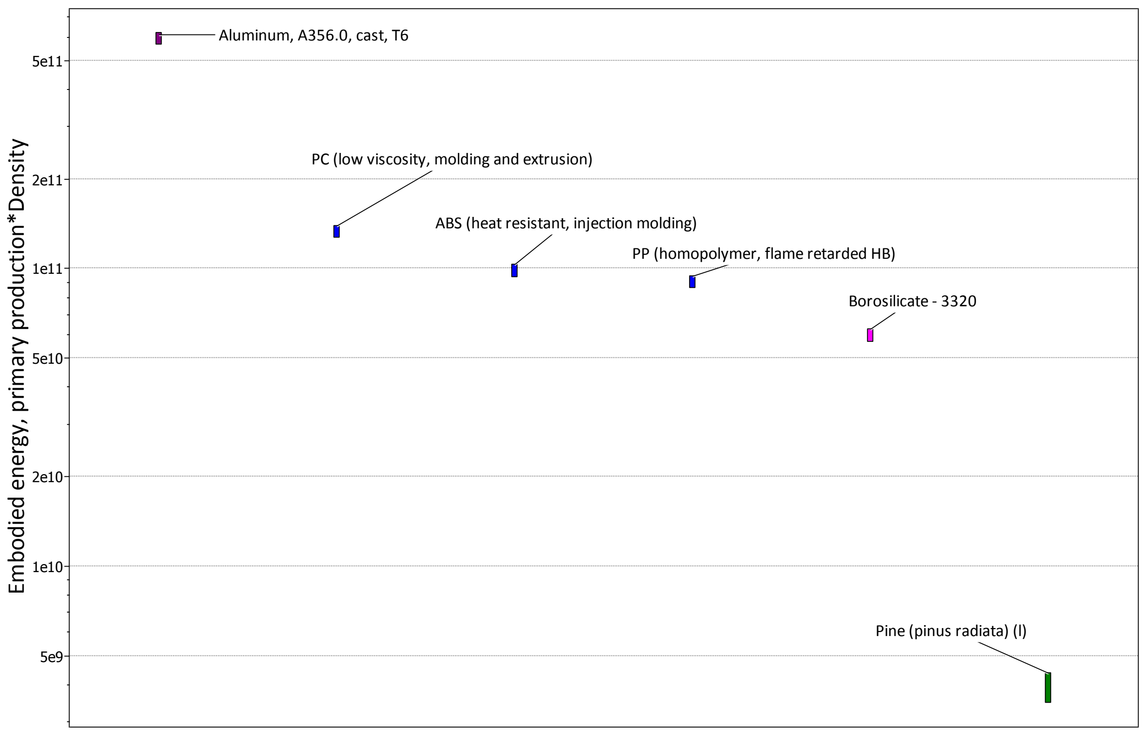


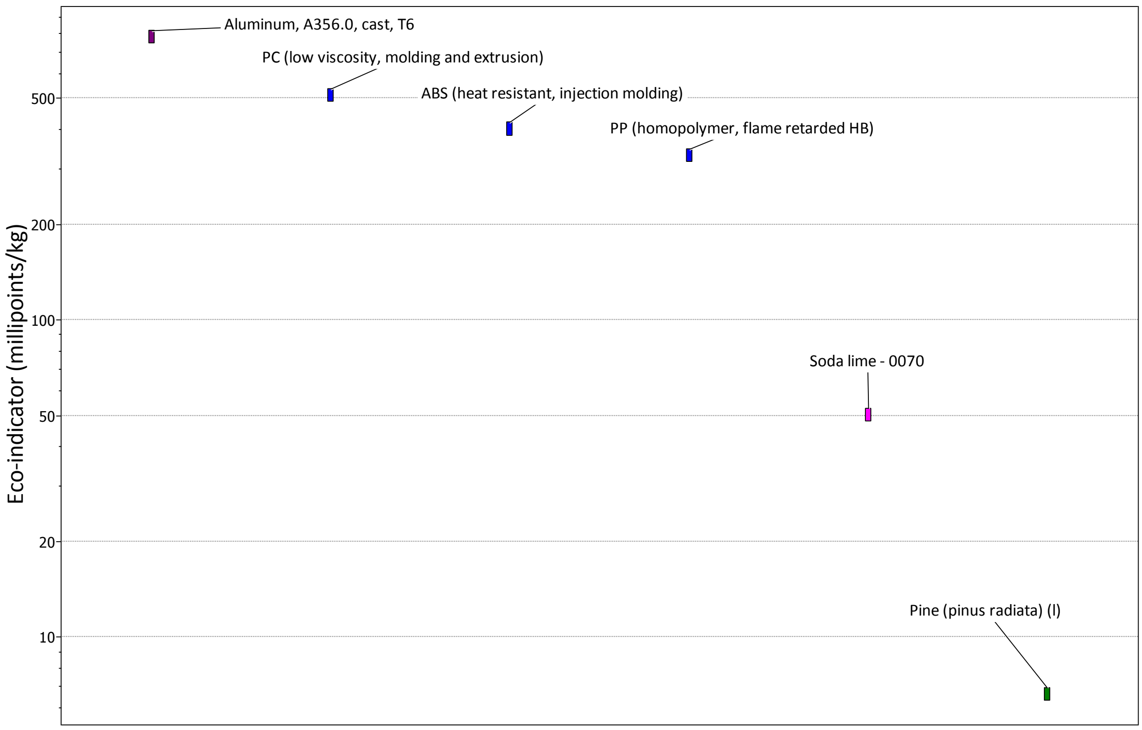
Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
PP (homopolymer, flame retarded HB)
ABS (heat resistant, injection molding)
Borosilicate - 3320
Pine (pinus radiata) (l)
10
5
2
1
0.5
CO2 footprint, primary production (kg/kg)

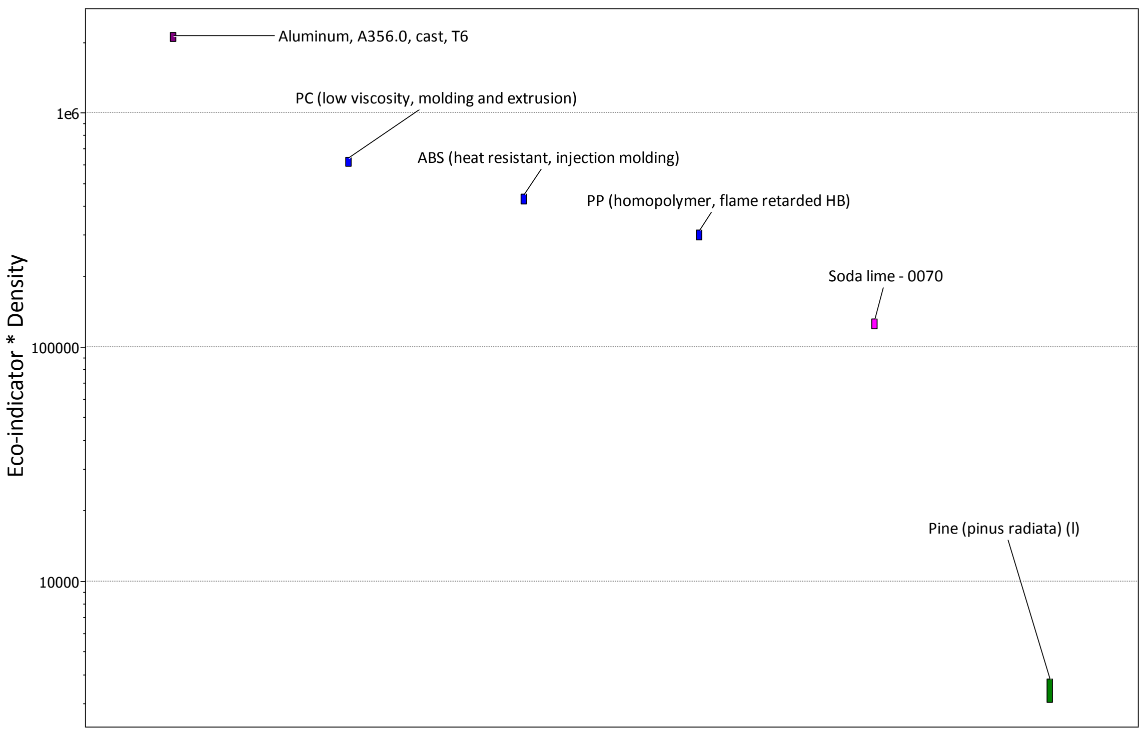


Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
PP (homopolymer, flame retarded HB)
ABS (heat resistant, injection molding)
Borosilicate - 3320
Pine (pinus radiata) (l)
2e8
1e8
5e7
2e7
1e7
Embodied energy, primary production (J/kg)


CO2 footprint, primary production*density
Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
ABS (heat resistant, injection molding)
PP (homopolymer, flame retarded HB)
Borosilicate - 3320
Pine (pinus radiata) (l)
20000
10000
5000
2000
1000
500
200


Embodied energy, primary production*Density
Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
ABS (heat resistant, injection molding)
PP (homopolymer, flame retarded HB)
Borosilicate - 3320
Pine (pinus radiata) (l)
5e11
2e11
1e11
5e10
2e10
1e10
5e9


Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
ABS (heat resistant, injection molding)
PP (homopolymer, flame retarded HB)
Soda lime - 0070
Pine (pinus radiata) (l)
Eco-indicator (millipoints/kg)
500
200
100
50
20
10


Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
ABS (heat resistant, injection molding)
PP (homopolymer, flame retarded HB)
Soda lime - 0070
Pine (pinus radiata) (l)
Eco-indicator * Density
1e6
100000
10000

3. Additional eco indicator graphs

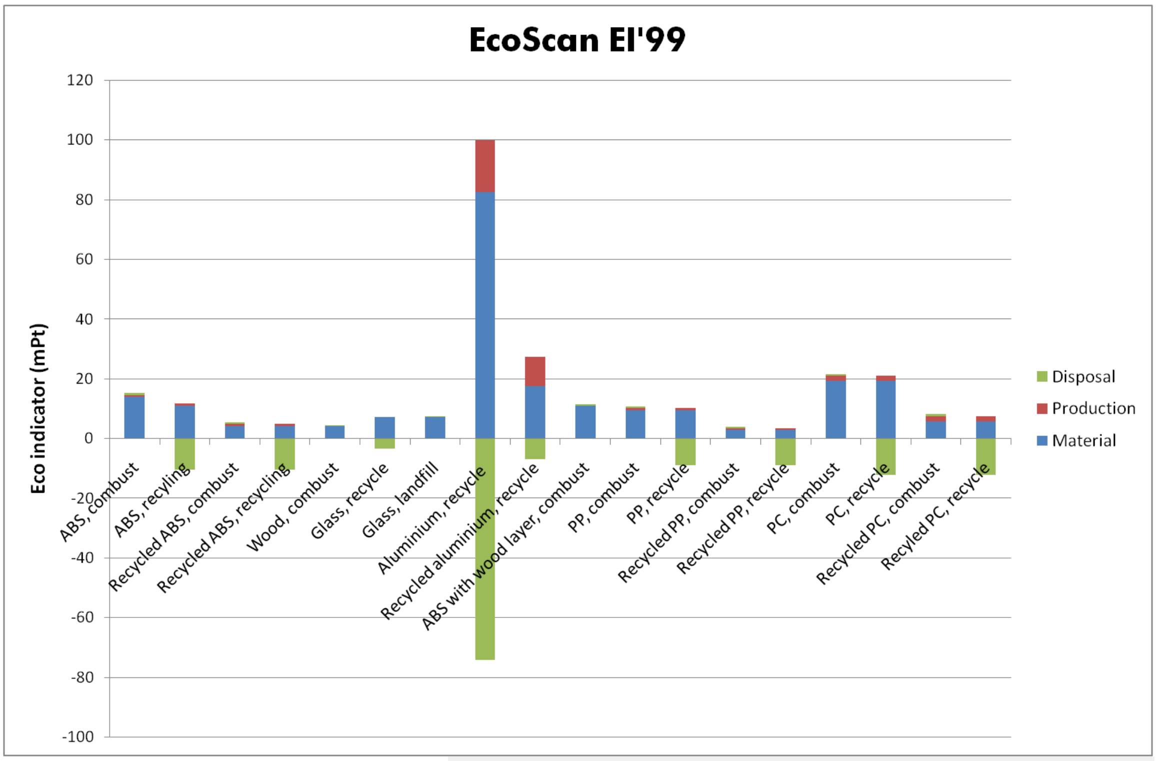


Figure 3a: Division of eco indictor values

Note
In the values of glass and wood the values for material and disposal are altogether.

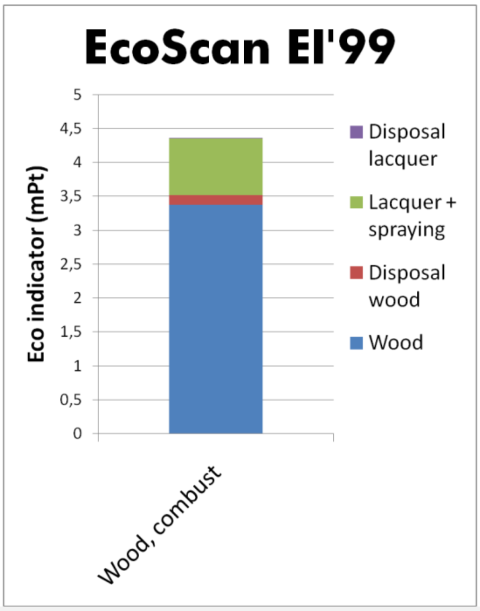


Figure 3b: Division of wood with lacquer

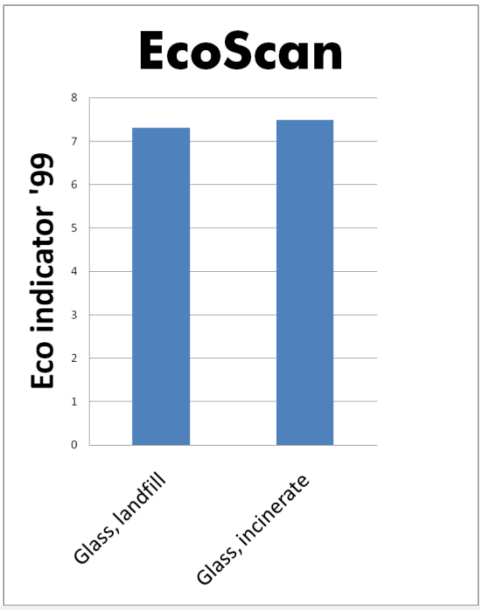
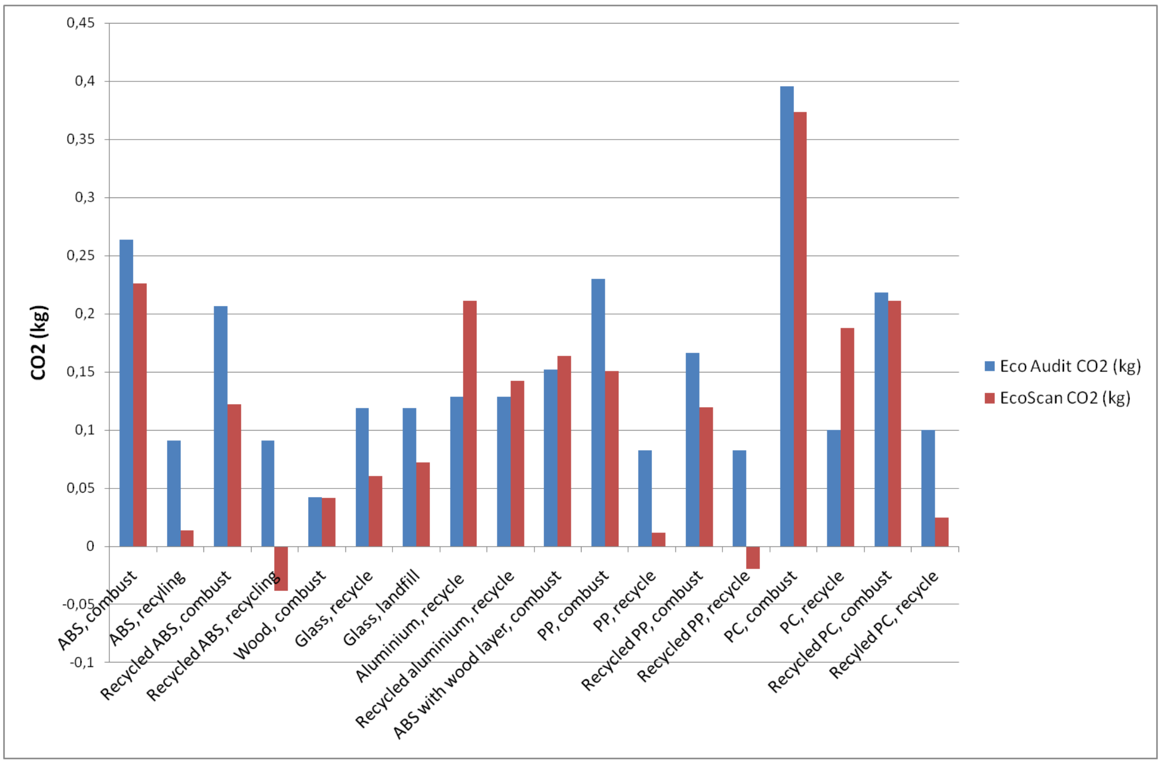


Figure 3c: Glass disposal methods eco indicator values

4. CO2 footprint in EcoScan and Eco Audit



5. Knowledge transfer

For the knowledge transfer on how to apply Granta CES Selector in the Philips product development process the choice was made to give a presentation. Besides the presentation itself a few additional sets of slides have been developed. One of these sets is focussing on data directly applicable to the current development and case study. The other presentation is meant for self study of the Philips employees on how to use the Granta CES Selector in their daily work. In this appendix some more explanation on the knowledge transfer will be given. The learning goals, content and the form of education is discussed.

5.1 Form of education

The knowledge of sustainable material selection needs to be transferred to the people working at Philips. The goal is that the product engineers and the function developers can make well-founded discussion without the support of sustainability experts. The knowledge transfer needs to include the basic information on sustainable material choices for Philips appliances. This can be done in many different ways. It could be written in a report, sheets could be used, a movie could be used, etc. The people working at Philips are in general very busy. They won't have time to read a whole report. Besides that, the communication within Philips mostly occurs via PowerPoint sheets. These sheets are presented and placed on SharePoint, where they are available for all interested Philips employees. It will be best to stick to the current way of working within Philips, to increase the change that the documents will be used. Therefore PowerPoint sheets are made to communicate the information to the IDA community. One of the PowerPoint presentations is used for an oral presentation concluding this assignment.

5.2 Presentation

A presentation is given for some product engineers and function developers at the 21st of July. In this paragraph the learning goals, content and the realization is discussed. The development of the final presentation is based on this approach.

Learning goals

The learning goals of the presentation are:

- **To introduce the Granta CES Selector.** For now, there is no or little knowledge on the existence of this software program at Philips. The goal is to introduce the program to trigger people to work with it.
- **To introduce sustainability in material selection.** There is done research and implementation on energy efficiency within Philips, but about overall sustainability there is not a lot of knowledge, only some specific people have the necessary experiences. Due to this presentation an introduction to sustainability is given and in specific on material selection.
- **To introduce the step-by-step plan for sustainable material selection.** The step-by-step plan explained in Chapter 6 will be introduced. This plan is developed to provide an understandable and easy way to make well-founded material choices based on sustainability.

Content

Now the learning goals are clear the content will be developed. A short introduction on the Granta CES Selector will be given and a demonstration on how to work with it. An introduction to sustainability and material choices will be given. This will be based on the information provided in Chapter 3. And the step-by-step plan will be introduced. To explain the step-by-step plan examples of the SENSEO will be used. This will give the Philips employees a better understanding of the implementation of the step-by-step plan. The books, papers, internet sites, etc where more information can be found will be given as well. So people could find more information if they want.

Realization

With the learning goals and the content clear the sheets can be made. The fonts used are the same for all the PowerPoint presentations that are made, and the same as the report, to keep unity. These are other fonts as used in the standard sheets of Philips, to give the sheets a personal touch. The lay-out is the same as used within Philips to be sure they will be taken seriously. This is a very basic lay-out and gives the information that is needed: confidentiality, the author and data, sheets numbering and the company name. In this I included the University of Twente.

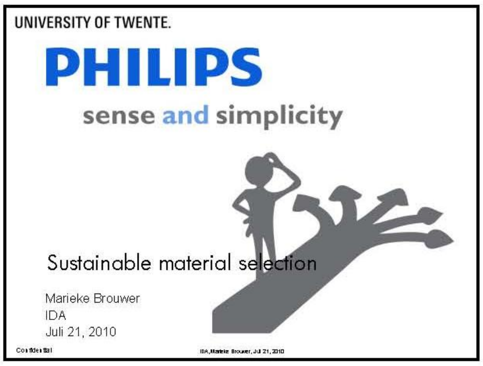
5.3 Slides

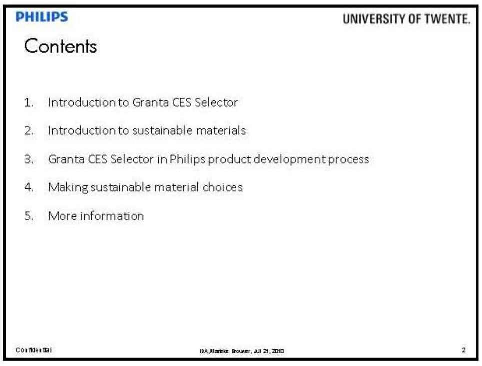
All sheets made for Philips have the same lay-out, same colouring and same fonts. The sheets about the Granta CES Selector are made like a guide. The information is divided in different chapters providing the overview people need when working with a software program. The tabs on the right of the sheets represent the different things that are possible with the program. The sheets can be used as a guide that follows though the program, but it is also possible to use parts of the sheets for specific use of the program.
The sheets with the research data provide all the graphs used in this report. Some people don't have the time to read the whole case study. These sheets provide all the important information.

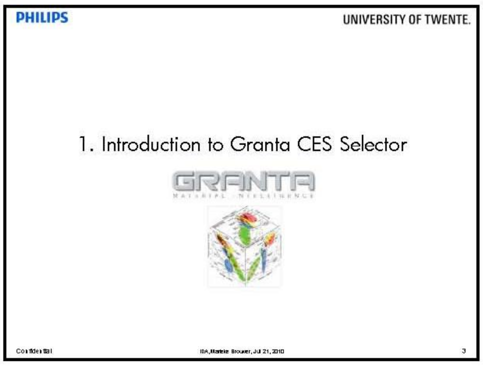
5.4 Report

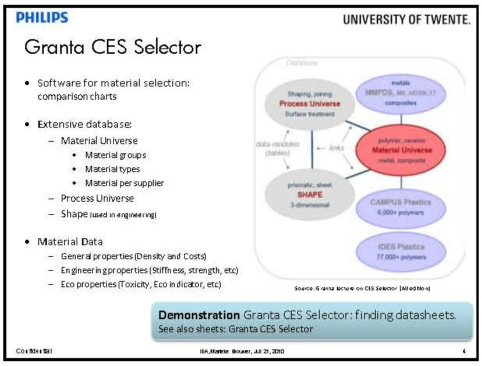
The report is written to provide all the information about the assignment. After reading the report it will be clear why conclusions are drawn and what information is used. The structure is based on giving the right information at the right time. First introductions on Philips, the Granta CES Selector and sustainable materials are given. Then the software tools that are used are compared, to give an impression of the differences in the input, methods and output of the different programs. Then a case study is done on sustainable material selection for the SENSEO using the different software tools. Afterwards the conclusion can be made on how to use the software programs within Philips and how to make sustainable material choices. A step-by-step plan is developed for that. Then the general conclusions on the assignment are given.

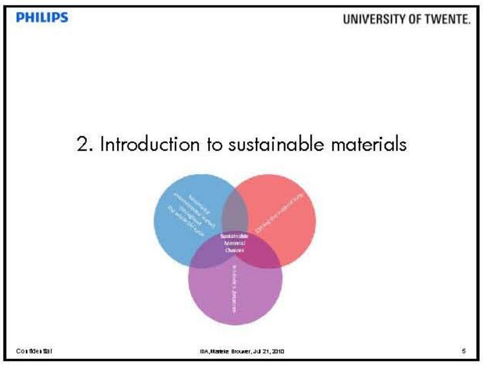
6. Sheets presentation at Philips: Sustainable Material Selection

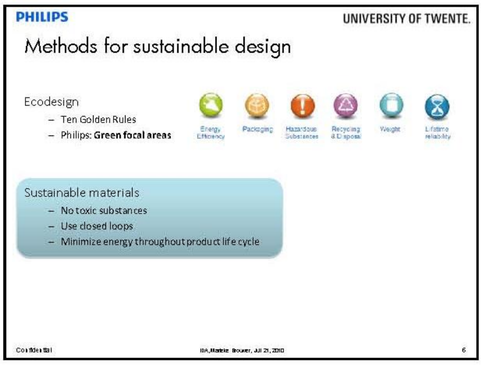




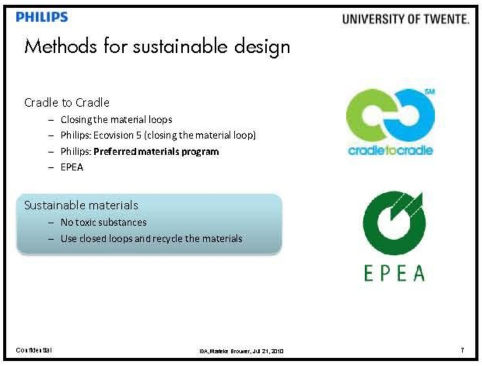


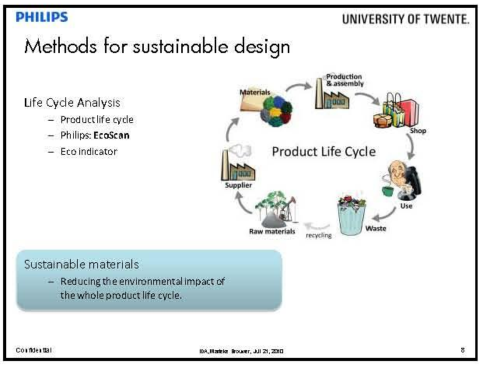


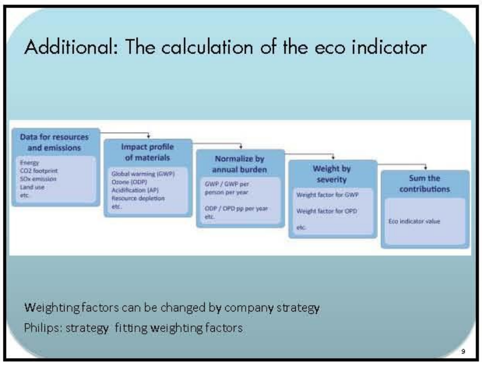


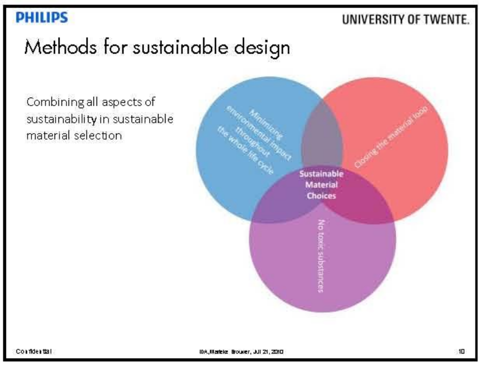


1

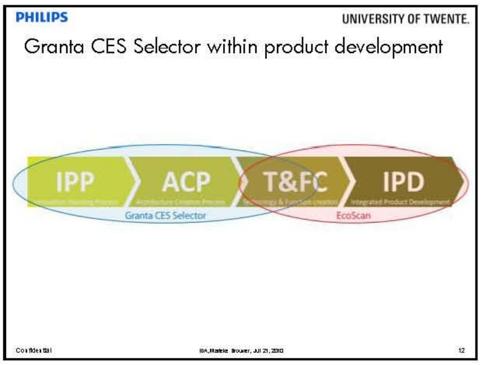

PHILIPS
UNIVERSITY OF TWENTE.
Methods for sustainable design
Cradle to Cradle
– Closing the material loops
– Philips: Ecovision 5 (closing the material loop)
– Philips: Preferred materials program
– EPEA
Sustainable materials
– No toxic substances
– Use closed loops and recycle the materials
cradletocradle
EPEA
Confidential
7

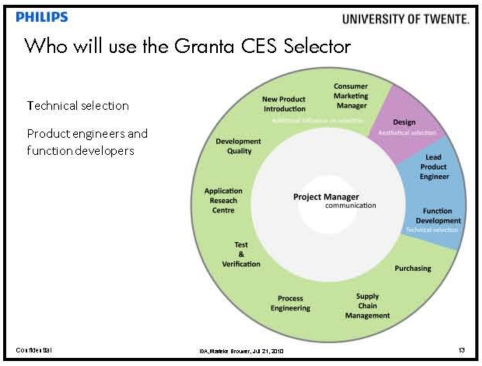

PHILIPS
UNIVERSITY OF TWENTE.
Methods for sustainable design
Life Cycle Analysis
– Product life cycle
– Philips: EcoScan
– Eco indicator
Product Life Cycle
Materials
Production & assembly
Shop
Use
Waste
recycling
Raw materials
Supplier
Sustainable materials
– Reducing the environmental impact of the whole product life cycle.
Confidential
8


Additional: The calculation of the eco indicator
Data for resources and emissions
Energy
CO2 footprint
SOx emission
Land use
etc
Impact profile of materials
Global warming (GWP)
Ozone (ODP)
Acidification (AP)
Resource depletion
etc.
Normalize by annual burden
GWP / GWP per person per year
ODP / OPD pp per year
etc.
Weight by severity
Weight factor for GWP
Weight factor for OPD
etc.
Sum the contributions
Eco indicator value
Weighting factors can be changed by company strategy
Philips: strategy fitting weighting factors
9

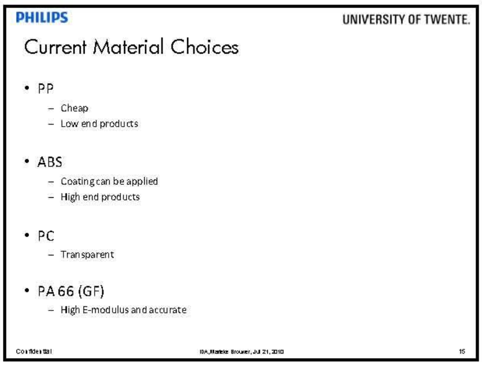

PHILIPS
UNIVERSITY OF TWENTE.
Methods for sustainable design
Combining all aspects of sustainability in sustainable material selection
Minimizing environmental impact throughout the whole life cycle
Closing the material loop
No toxic substances
Sustainable Material Choices
Confidential
10

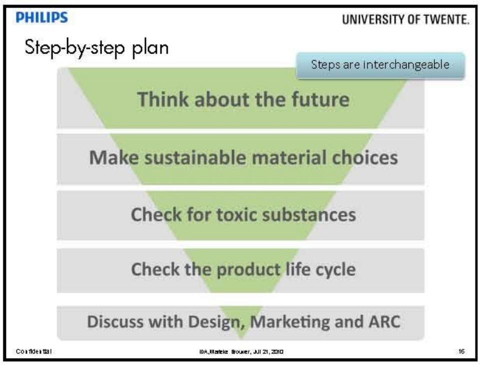

PHILIPS
UNIVERSITY OF TWENTE.
3. Granta CES Selector in a Philips product development project
PHILIPS
Confidential
11

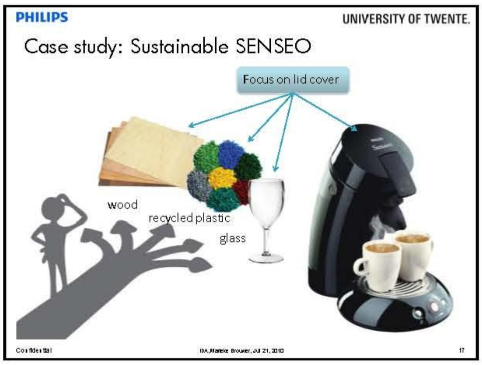

PHILIPS
UNIVERSITY OF TWENTE.
Granta CES Selector within product development
IPP
ACP
T&FC
IPD
Granta CES Selector
EcoScan
Confidential
12

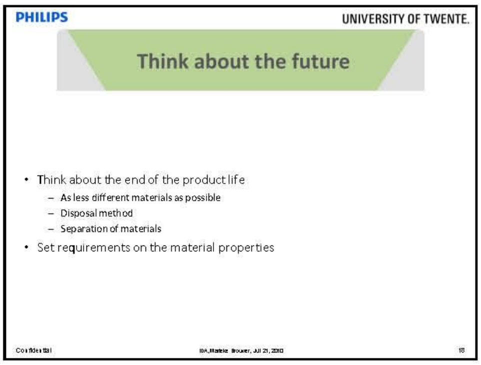

PHILIPS
UNIVERSITY OF TWENTE.
Who will use the Granta CES Selector
Technical selection
Product engineers and function developers
Consumer Marketing Manager
New Product Introduction
Design
Development Quality
Lead Product Engineer
Application Reseach Centre
Project Manager
communication
Function Development
Test & Verification
Purchasing
Process Engineering
Supply Chain Management
Confidential
13


PHILIPS
UNIVERSITY OF TWENTE.
4. Making sustainable material choices
Confidential
14


PHILIPS
UNIVERSITY OF TWENTE.
Current Material Choices
• PP
– Cheap
– Low end products
• ABS
– Coating can be applied
– High end products
• PC
– Transparent
• PA 66 (GF)
– High E-modulus and accurate
Confidential
15

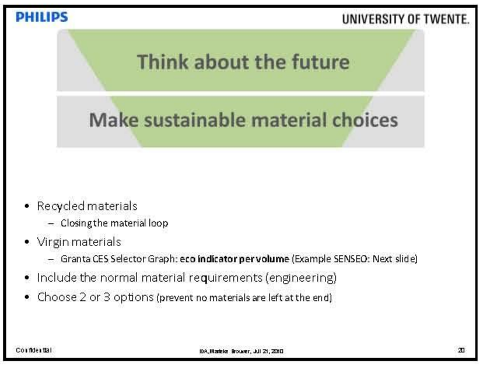

PHILIPS
UNIVERSITY OF TWENTE.
Step-by-step plan
Steps are interchangeable
Think about the future
Make sustainable material choices
Check for toxic substances
Check the product life cycle
Discuss with Design, Marketing and ARC
Confidential
16

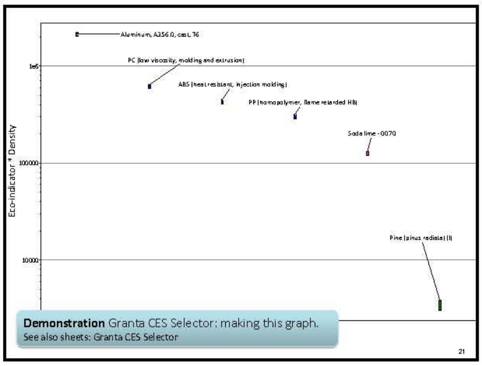

PHILIPS
UNIVERSITY OF TWENTE.
Case study: Sustainable SENSEO
Focus on lid cover
wood
recycled plastic
glass
Confidential
17


PHILIPS
UNIVERSITY OF TWENTE.
Think about the future
• Think about the end of the product life
– As less different materials as possible
– Disposal method
– Separation of materials
• Set requirements on the material properties
Confidential
18

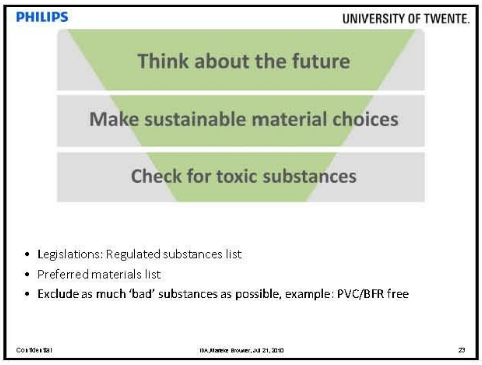
3


PHILIPS
UNIVERSITY OF TWENTE.
Case study: Sustainable SENSEO
Think about the future
• Disposal = recycling
• As less different materials as possible: less waste streams
• Design for disassembly: separation of materials
• Set requirements on the material properties
– No toxic substances
– Recyclable materials or low impact materials
Confidential
IDA,Marieke Brouwer, Jul 21, 2010
19


PHILIPS
UNIVERSITY OF TWENTE.
Think about the future
Make sustainable material choices
• Recycled materials
– Closing the material loop
• Virgin materials
– Granta CES Selector Graph: **eco indicator per volume** (Example SENSEO: Next slide)
• Include the normal material requirements (engineering)
• Choose 2 or 3 options (prevent no materials are left at the end)
Confidential
IDA,Marieke Brouwer, Jul 21, 2010
20

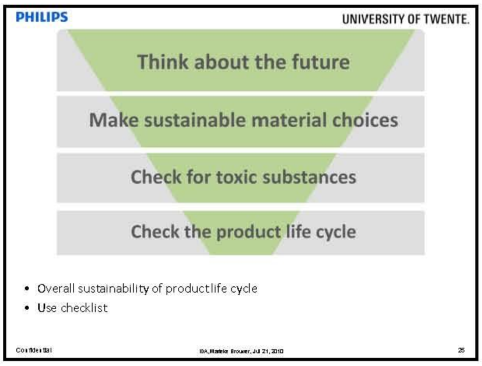

Aluminum, A356.0, cast, T6
PC (low viscosity, molding and extrusion)
ABS (heat resistant, injection molding)
PP (homopolymer, flame retarded HB)
Soda lime - 0070
Pine (pinus radiata) (l)
1e5
100000
10000
Eco-indicator * Density
Demonstration Granta CES Selector: making this graph.
See also sheets: Granta CES Selector
21

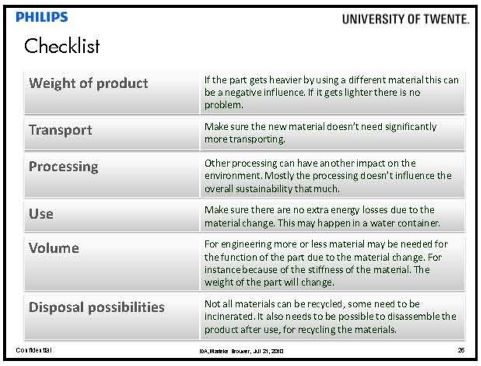

PHILIPS
UNIVERSITY OF TWENTE.
Case study: Sustainable SENSEO
Make sustainable material choices
• Options
– Graph in CES Selector, top 3: **Wood, Glass and PP**
– Closing materials loop: **Glass, PP, ABS and PC recycling**
• Exclude materials that do not meet the normal material requirements
Confidential
IDA,Marieke Brouwer, Jul 21, 2010
22

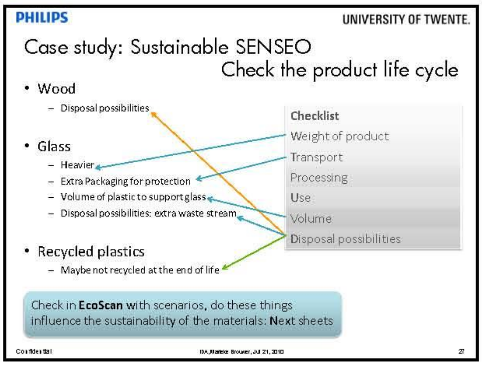

PHILIPS
UNIVERSITY OF TWENTE.
Think about the future
Make sustainable material choices
Check for toxic substances
• Legislations: Regulated substances list
• Preferred materials list
• Exclude as much 'bad' substances as possible, example: PVC/BFR free
Confidential
IDA,Marieke Brouwer, Jul 21, 2010
23

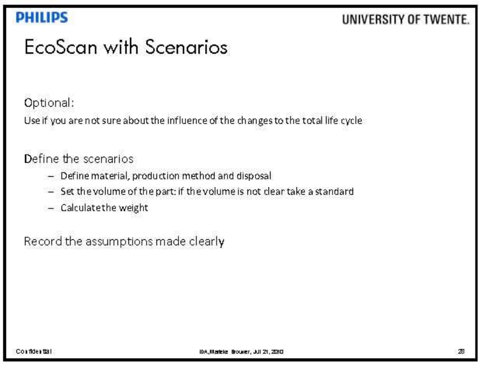

PHILIPS
UNIVERSITY OF TWENTE.
Case study: Sustainable SENSEO
Check for toxic substances
• Legislations
• Regulated Substances List
• Exclude other 'bad' substances: PVC, BFR, etc
• Preferred materials list **(Cradle to Cradle)**
– Trustful materials
Confidential
IDA,Marieke Brouwer, Jul 21, 2010
24

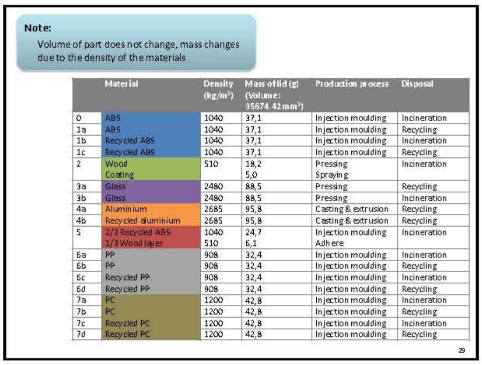
4



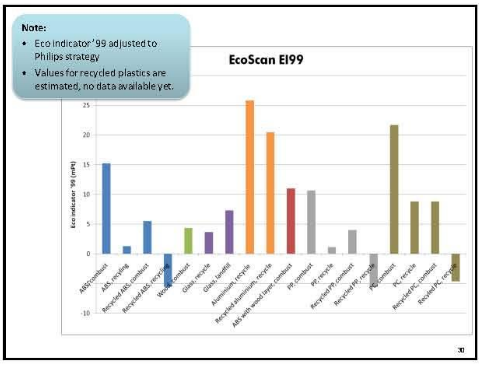




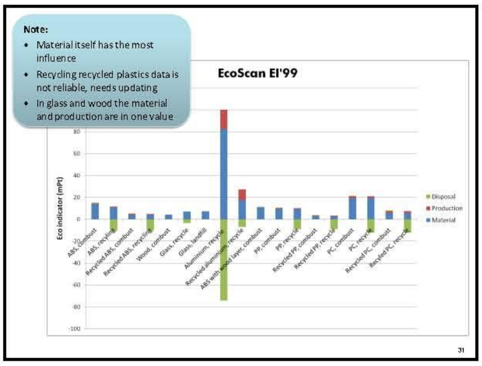


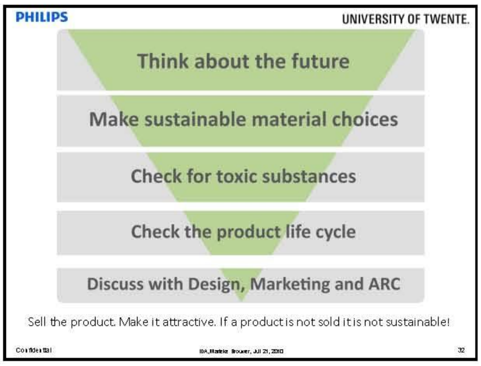


	Material	Density (kg/m³)	Mass of lid (g) (Volume: 35674.42 mm³)	Production process	Disposal
0	ABS	1040	37,1	Injection moulding	Incineration
1a	ABS	1040	37,1	Injection moulding	Recycling
1b	Recycled ABS	1040	37,1	Injection moulding	Incineration
1c	Recycled ABS	1040	37,1	Injection moulding	Recycling
2	Wood Coating	510	18,2 5,0	Pressing Spraying	Incineration
3a	Glass	2480	88,5	Pressing	Recycling
3b	Glass	2480	88,5	Pressing	Incineration
4a	Aluminium	2685	95,8	Casting & extrusion	Recycling
4b	Recycled aluminium	2685	95,8	Casting & extrusion	Recycling
5	2/3 Recycled ABS 1/3 Wood layer	1040 510	24,7 6,1	Injection moulding Adhere	Incineration
6a	PP	908	32,4	Injection moulding	Incineration
6b	PP	908	32,4	Injection moulding	Recycling
6c	Recycled PP	908	32,4	Injection moulding	Incineration
6d	Recycled PP	908	32,4	Injection moulding	Recycling
7a	PC	1200	42,8	Injection moulding	Incineration
7b	PC	1200	42,8	Injection moulding	Recycling
7c	Recycled PC	1200	42,8	Injection moulding	Incineration
7d	Recycled PC	1200	42,8	Injection moulding	Recycling

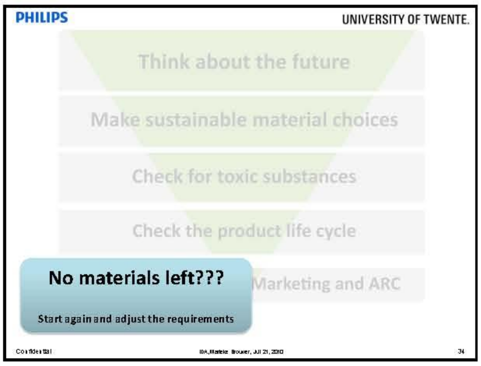


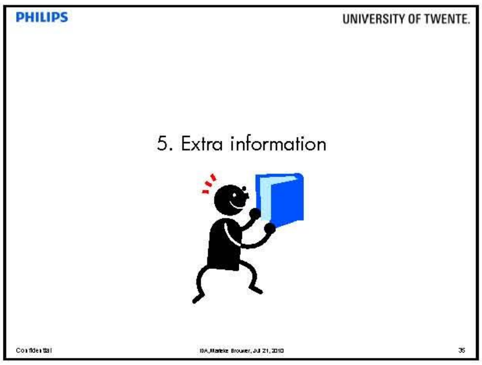
5

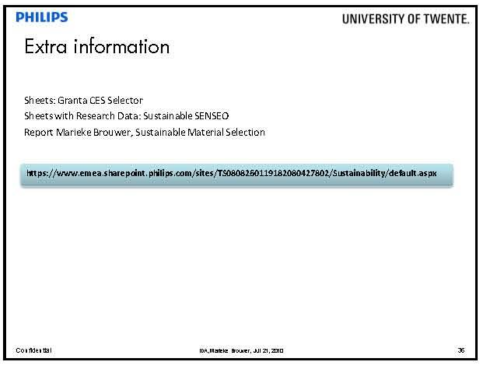

Note:
Material itself has the most influence
Recycling recycled plastics data is not reliable, needs updating
In glass and wood the material and production are in one value
EcoScan EI'99
Eco indicator (mPt)
Disposal
Production
Material
31


PHILIPS
UNIVERSITY OF TWENTE.
Think about the future
Make sustainable material choices
Check for toxic substances
Check the product life cycle
Discuss with Design, Marketing and ARC
Sell the product. Make it attractive. If a product is not sold it is not sustainable!
Confidential
32

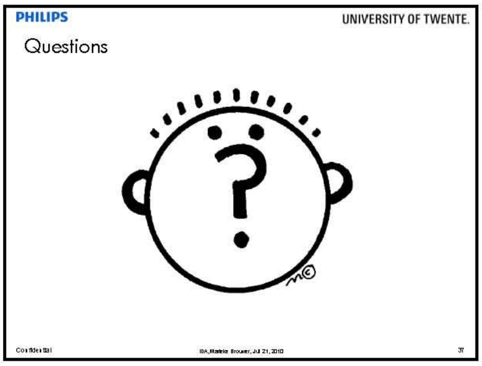

PHILIPS
UNIVERSITY OF TWENTE.
Case study: Sustainable SENSEO
Discuss with Design, Marketing and ARC
ARC: consumer doesn't link wood to sustainability
Exclude
Conclusion: different ways to look at sustainability.
Think clearly and make well-founded decisions
Confidential
33

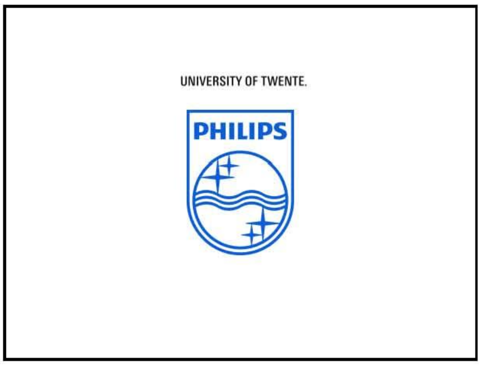

PHILIPS
UNIVERSITY OF TWENTE.
Think about the future
Make sustainable material choices
Check for toxic substances
Check the product life cycle
Marketing and ARC
No materials left???
Start again and adjust the requirements
Confidential
34


PHILIPS
UNIVERSITY OF TWENTE.
5. Extra information
Confidential
35


PHILIPS
UNIVERSITY OF TWENTE.
Extra information
Sheets: Granta CES Selector
Sheets with Research Data: Sustainable SENSEO
Report Marieke Brouwer, Sustainable Material Selection
https://www.emea.sharepoint.philips.com/sites/TS0808260119182080427802/Sustainability/default.aspx
Confidential
36

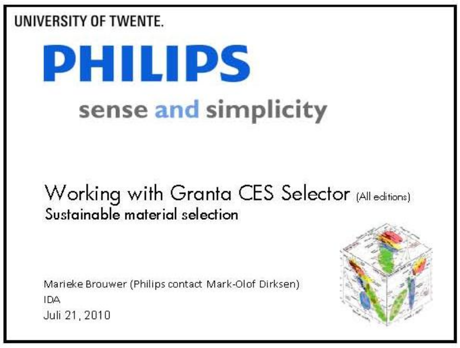
6

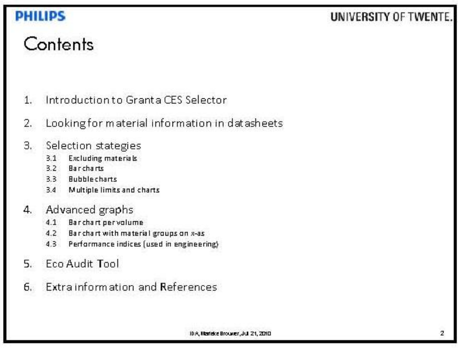

PHILIPS
UNIVERSITY OF TWENTE.
Questions

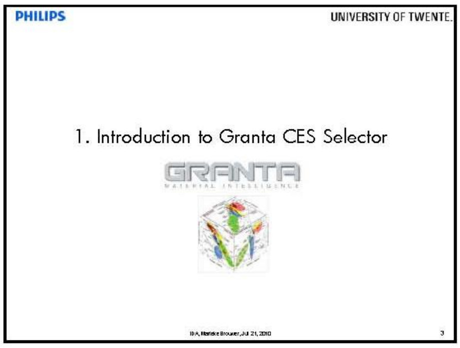

UNIVERSITY OF TWENTE.
PHILIPS

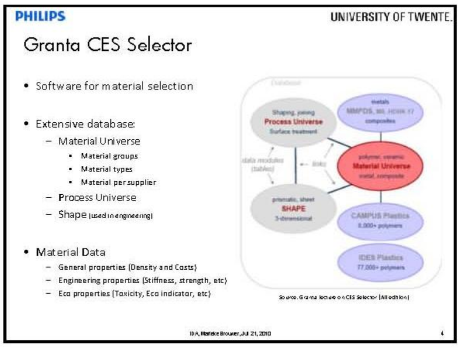
7

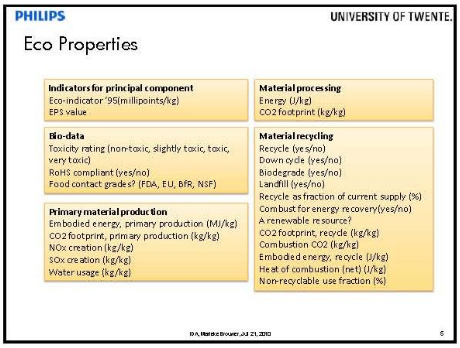
7. Sheets Granta CES Selector



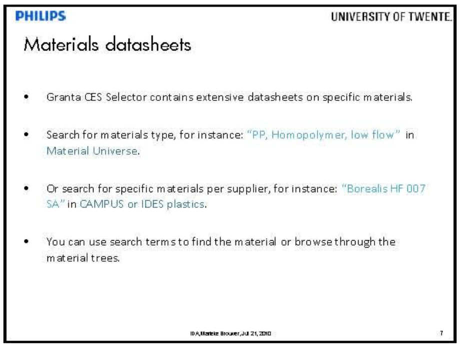


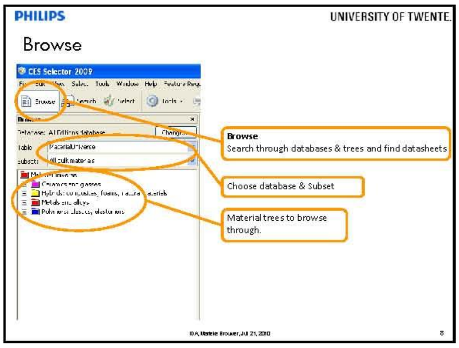


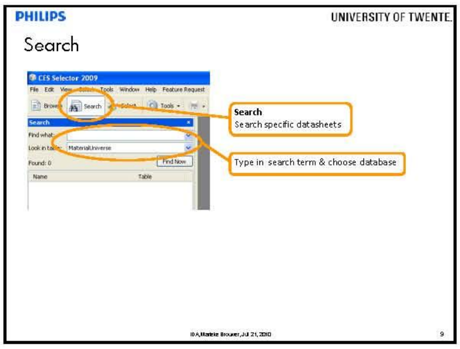


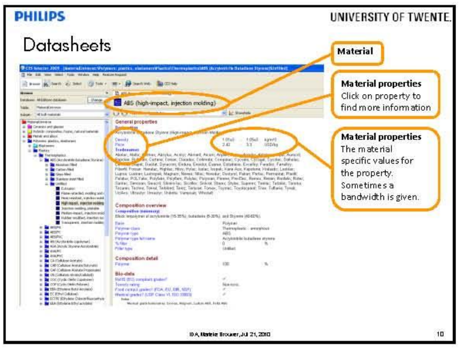


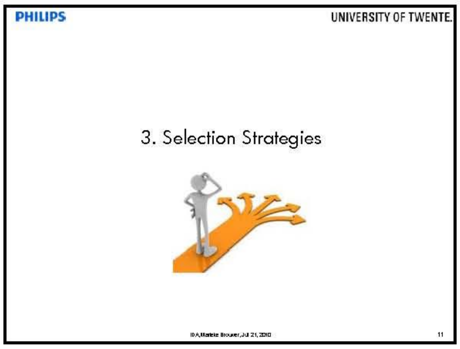
1

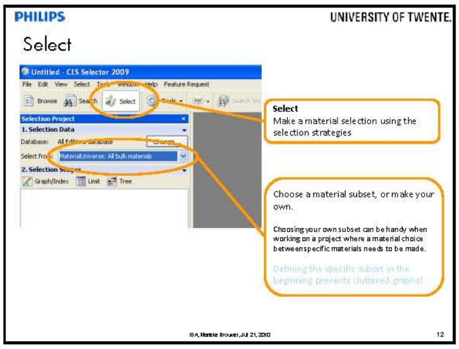

PHILIPS
UNIVERSITY OF TWENTE.
Materials datasheets
Granta CES Selector contains extensive datasheets on specific materials.
Search for materials type, for instance: "PP, Homopolymer, low flow" in Material Universe.
Or search for specific materials per supplier, for instance: "Borealis HF 007 SA" in CAMPUS or IDES plastics.
You can use search terms to find the material or browse through the material trees.
7


PHILIPS
UNIVERSITY OF TWENTE.
Browse
CES Selector 2009
Browse
Search through databases & trees and find datasheets
Choose database & Subset
Material trees to browse through.
8


PHILIPS
UNIVERSITY OF TWENTE.
Search
CES Selector 2009
Search
Search specific datasheets
Type in search term & choose database
9


PHILIPS
UNIVERSITY OF TWENTE.
Datasheets
Material
Material properties
Click on property to find more information
Material properties
The material specific values for the property. Sometimes a bandwidth is given.
10


PHILIPS
UNIVERSITY OF TWENTE.
3. Selection Strategies
11


PHILIPS
UNIVERSITY OF TWENTE.
Select
Untitled - CES Selector 2009
Select
Make a material selection using the selection strategies
Choose a material subset, or make your own.
Choosing your own subset can be handy when working on a project where a material choice between specific materials needs to be made.
Defining the specific subset in the beginning prevents cluttered graphs!
12

Selection strategies

Select the optimal materials by different selection strategies.

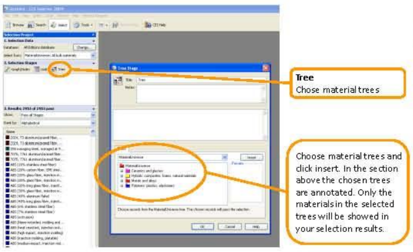
3.1 Excluding materials
3.2 Bar charts
3.3 Bubble charts (with trade of line)
3.4 Multiple limits and charts

3.1 Excluding materials

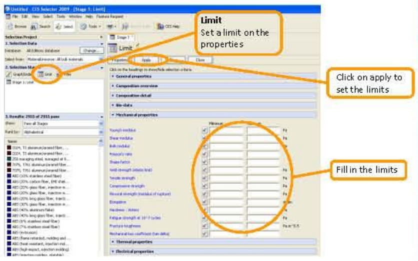
- Trees
  The materials are divided into material groups. When you only want information from certain material groups you can select these groups and exclude the rest.

- Limits
  By setting limits on the material properties you can exclude materials that do not meet the constraints. For instance, the materials may not be toxic. The limit can be only the "non-toxic materials" pass. Or only materials that have a "maximum service temperature" of minimal 80°C.

Selecting trees



Setting limits

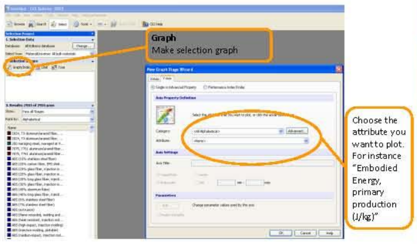


3.2 Bar charts

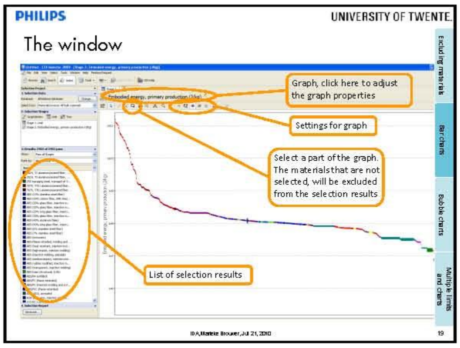
By making a bar chart materials can be compared on one property.

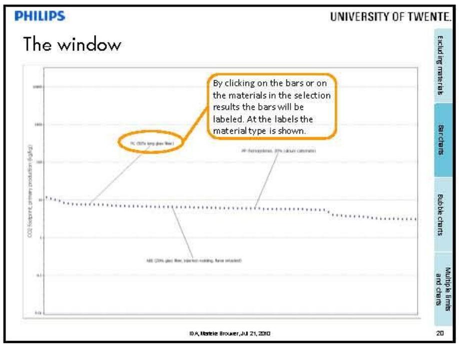
In a bar chart a box can be graphed which selects a range of materials. The materials are out of the box will be excluded from the selection results.

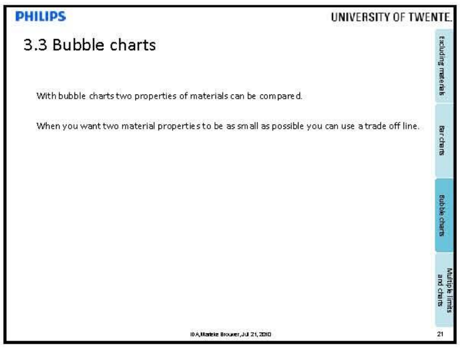
Making a bar chart

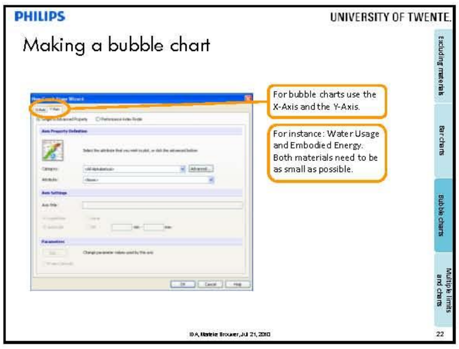


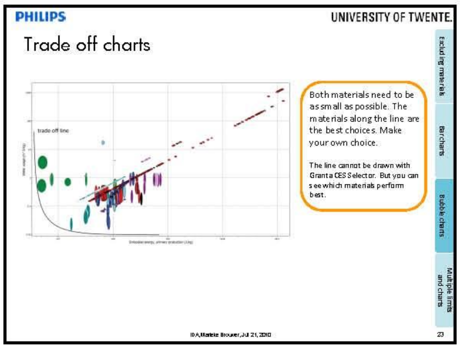
3

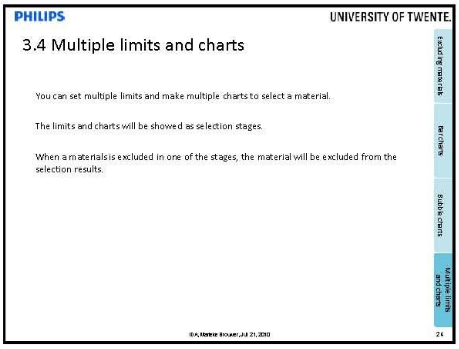

PHILIPS
UNIVERSITY OF TWENTE.
The window
Graph, click here to adjust the graph properties
Settings for graph
Select a part of the graph. The materials that are not selected, will be excluded from the selection results
List of selection results
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
19


PHILIPS
UNIVERSITY OF TWENTE.
The window
By clicking on the bars or on the materials in the selection results the bars will be labeled. At the labels the material type is shown.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
20

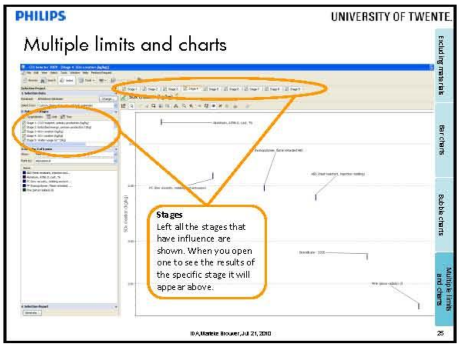

PHILIPS
UNIVERSITY OF TWENTE.
3.3 Bubble charts
With bubble charts two properties of materials can be compared.
When you want two material properties to be as small as possible you can use a trade off line.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
21

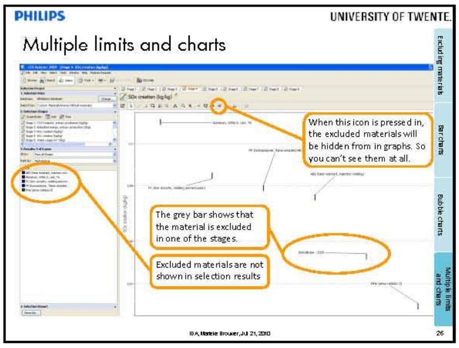

PHILIPS
UNIVERSITY OF TWENTE.
Making a bubble chart
For bubble charts use the X-Axis and the Y-Axis.
For instance: Water Usage and Embodied Energy. Both materials need to be as small as possible.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
22


PHILIPS
UNIVERSITY OF TWENTE.
Trade off charts
trade off line
Both materials need to be as small as possible. The materials along the line are the best choices. Make your own choice.
The line cannot be drawn with Granta CES Selector. But you can see which materials perform best.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
23

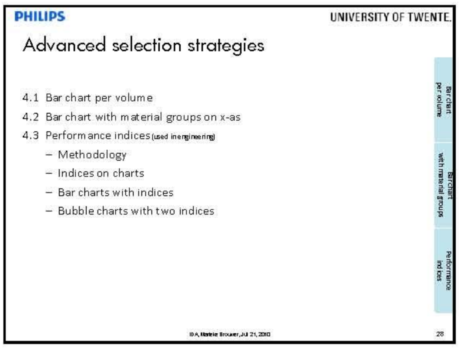

PHILIPS
UNIVERSITY OF TWENTE.
3.4 Multiple limits and charts
You can set multiple limits and make multiple charts to select a material.
The limits and charts will be showed as selection stages.
When a materials is excluded in one of the stages, the material will be excluded from the selection results.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
24

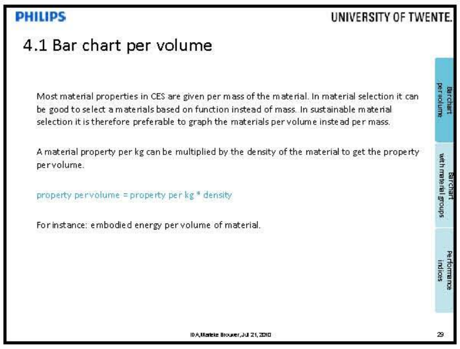
4

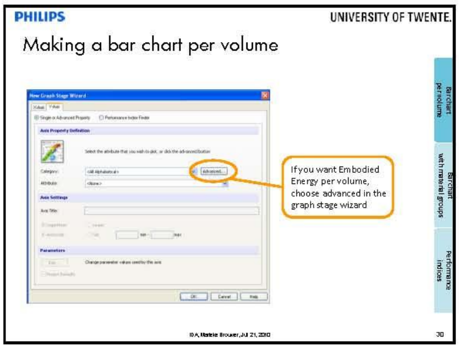

PHILIPS
UNIVERSITY OF TWENTE.
Multiple limits and charts
Stages
Left all the stages that have influence are shown. When you open one to see the results of the specific stage it will appear above.
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
IDA, Marieke Brouwer, Jul 21, 2010
25


PHILIPS
UNIVERSITY OF TWENTE.
Multiple limits and charts
SDx creation (kg/kg)
When this icon is pressed in, the excluded materials will be hidden from in graphs. So you can't see them at all.
The grey bar shows that the material is excluded in one of the stages.
Excluded materials are not shown in selection results
Excluding materials
Bar charts
Bubble charts
Multiple limits and charts
IDA, Marieke Brouwer, Jul 21, 2010
26

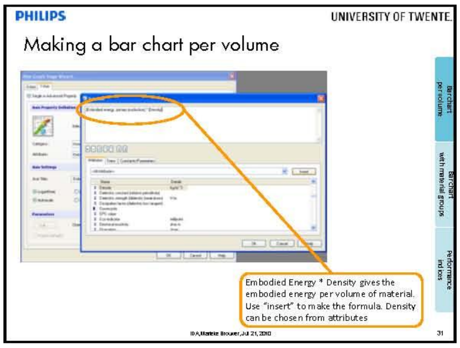

PHILIPS
UNIVERSITY OF TWENTE.
4. Advanced selection strategies
IDA, Marieke Brouwer, Jul 21, 2010
27

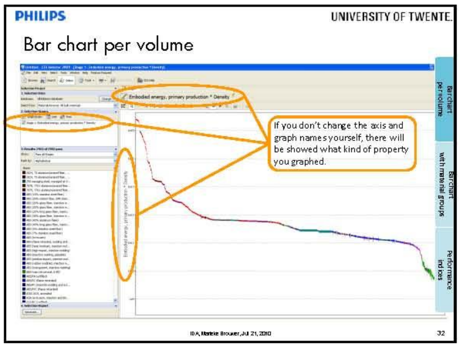

PHILIPS
UNIVERSITY OF TWENTE.
Advanced selection strategies
4.1 Bar chart per volume
4.2 Bar chart with material groups on x-as
4.3 Performance indices (used in engineering)
– Methodology
– Indices on charts
– Bar charts with indices
– Bubble charts with two indices
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
28

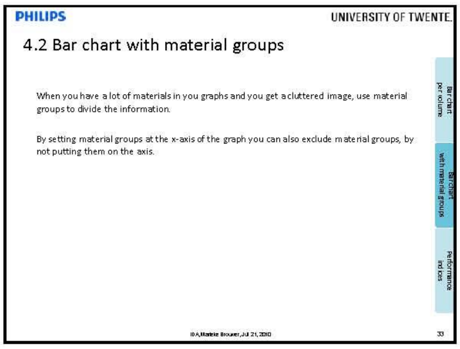

PHILIPS
UNIVERSITY OF TWENTE.
4.1 Bar chart per volume
Most material properties in CES are given per mass of the material. In material selection it can be good to select a materials based on function instead of mass. In sustainable material selection it is therefore preferable to graph the materials per volume instead per mass.
A material property per kg can be multiplied by the density of the material to get the property per volume.
property per volume = property per kg * density
For instance: embodied energy per volume of material.
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
29

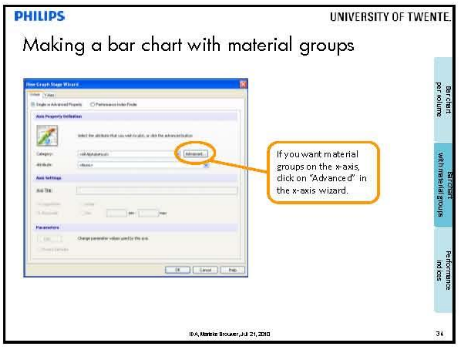

PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart per volume
New Graph Stage Wizard
If you want Embodied Energy per volume, choose advanced in the graph stage wizard
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
30

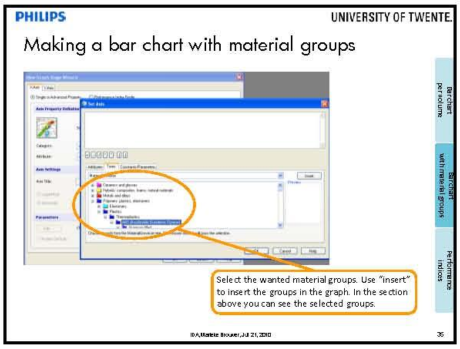
5

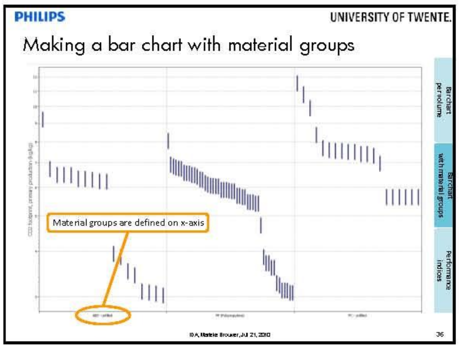

PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart per volume
Embodied Energy * Density gives the embodied energy per volume of material. Use "insert" to make the formula. Density can be chosen from attributes
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
31


PHILIPS
UNIVERSITY OF TWENTE.
Bar chart per volume
Embodied energy, primary production * Density
If you don't change the axis and graph names yourself, there will be showed what kind of property you graphed.
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
32


PHILIPS
UNIVERSITY OF TWENTE.
4.2 Bar chart with material groups
When you have a lot of materials in you graphs and you get a cluttered image, use material groups to divide the information.
By setting material groups at the x-axis of the graph you can also exclude material groups, by not putting them on the axis.
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
33


PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart with material groups
If you want material groups on the x-axis, click on "Advanced" in the x-axis wizard.
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
34


PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart with material groups
Select the wanted material groups. Use "insert" to insert the groups in the graph. In the section above you can see the selected groups.
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
35


PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart with material groups
Material groups are defined on x-axis
Bar chart per volume
Bar chart with material groups
Performance indices
IDA, Marieke Brouwer, Jul 21, 2010
36

6

PHILIPS UNIVERSITY OF TWENTE.

4.3 Performance indices (used in engineering)

Methodology of material selection

Making a bar chart with performance index finder

Bubble chart with index line

Bubble charts with two indices

Bar chart per volume | Bar chart with material groups | Performance indices

©A.Marieke Brouwer, Jul 21, 2010 37

PHILIPS UNIVERSITY OF TWENTE.

Methodology of material selection (Michael Ashby)

Analysis of component
- Function
- Constraints
- Maximize/minimize
- Free variables

⇩

Screen using constraints
- Eliminate materials that cannot do the job

⇩

Rank using objective
- Find the screened materials that do the job best

⇩

Seek documentation

⇩

Material choice

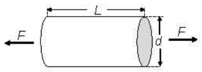
Bar chart per volume | Bar chart with material groups | Performance indices

©A.Marieke Brouwer, Jul 21, 2010 38

PHILIPS UNIVERSITY OF TWENTE.

Example

Maximize: stiffness
Minimize: mass



Performance index

$M_{stiffness, traction} = E/\rho$

Performance index finder
Bar chart with performance index

Logarithmic graph
E/ρ = straight line with scope 1

More information on Granta website and Michael Ashby books.

Bar chart per volume | Bar chart with material groups | Performance indices

©A.Marieke Brouwer, Jul 21, 2010 39

PHILIPS UNIVERSITY OF TWENTE.

4.3 Performance indices (used in engineering)

Methodology of material selection

Making a bar chart with performance index finder

Bubble chart with index line

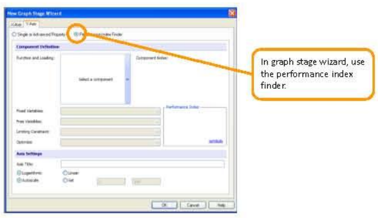
Bubble charts with two indices

Bar chart per volume | Bar chart with material groups | Performance indices

©A.Marieke Brouwer, Jul 21, 2010 40

PHILIPS UNIVERSITY OF TWENTE.

Making a bar chart with performance index finder

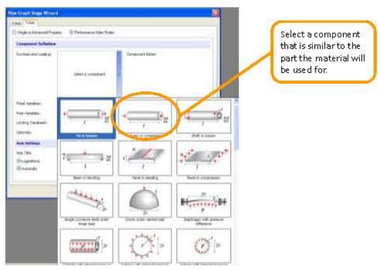


Bar chart per volume | Bar chart with material groups | Performance indices

©A.Marieke Brouwer, Jul 21, 2010 41

PHILIPS UNIVERSITY OF TWENTE.

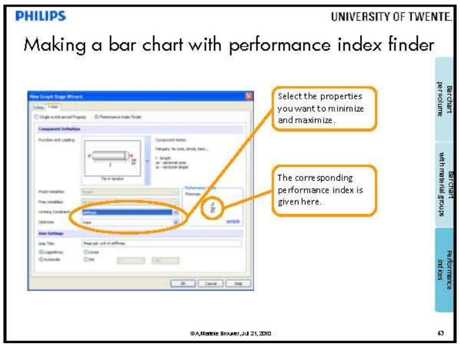
Making a bar chart with performance index finder

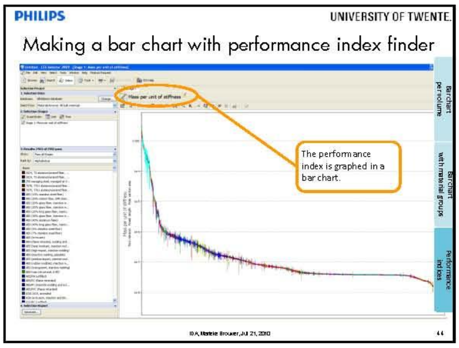


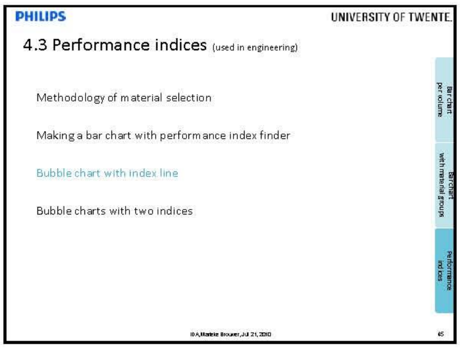
Bar chart per volume | Bar chart with material groups | Performance indices

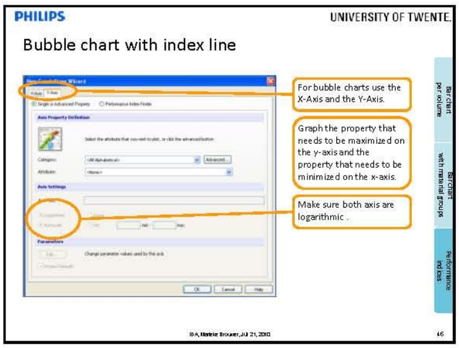
©A.Marieke Brouwer, Jul 21, 2010 42

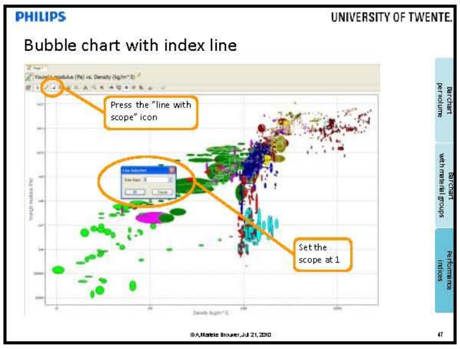
7

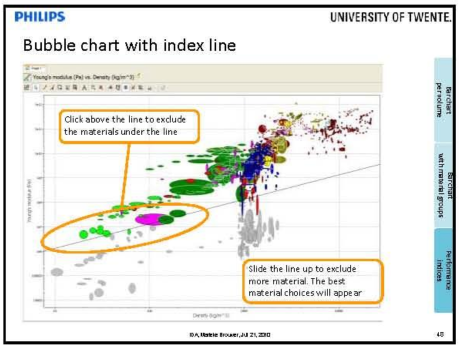

PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart with performance index finder
Select the properties you want to minimize and maximize.
The corresponding performance index is given here.
Barchart per volume
Barchart with material groups
Performance indices

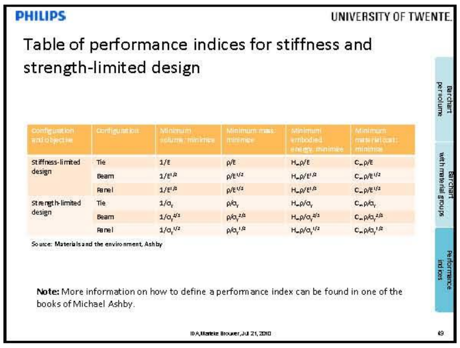

PHILIPS
UNIVERSITY OF TWENTE.
Making a bar chart with performance index finder
The performance index is graphed in a bar chart.
Barchart per volume
Barchart with material groups
Performance indices


PHILIPS
UNIVERSITY OF TWENTE.
4.3 Performance indices (used in engineering)
Methodology of material selection
Making a bar chart with performance index finder
Bubble chart with index line
Bubble charts with two indices
Barchart per volume
Barchart with material groups
Performance indices

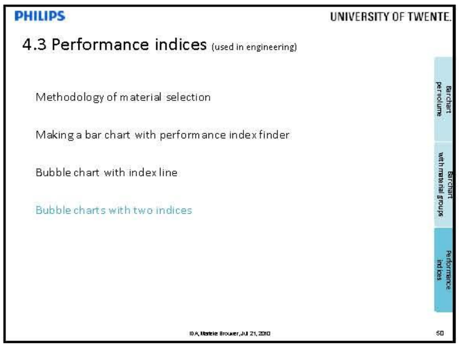

PHILIPS
UNIVERSITY OF TWENTE.
Bubble chart with index line
For bubble charts use the X-Axis and the Y-Axis.
Graph the property that needs to be maximized on the y-axis and the property that needs to be minimized on the x-axis.
Make sure both axis are logarithmic.
Barchart per volume
Barchart with material groups
Performance indices

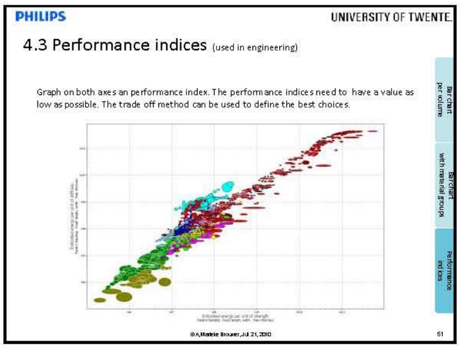

PHILIPS
UNIVERSITY OF TWENTE.
Bubble chart with index line
Press the "line with scope" icon
Set the scope at 1
Barchart per volume
Barchart with material groups
Performance indices

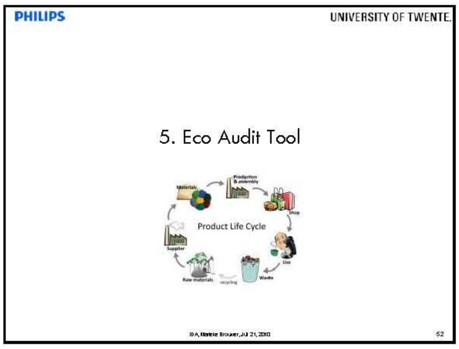

PHILIPS
UNIVERSITY OF TWENTE.
Bubble chart with index line
Click above the line to exclude the materials under the line
Slide the line up to exclude more material. The best material choices will appear
Barchart per volume
Barchart with material groups
Performance indices

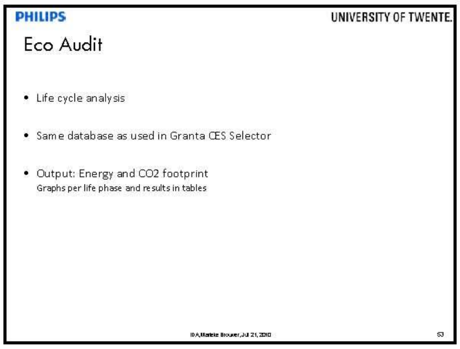


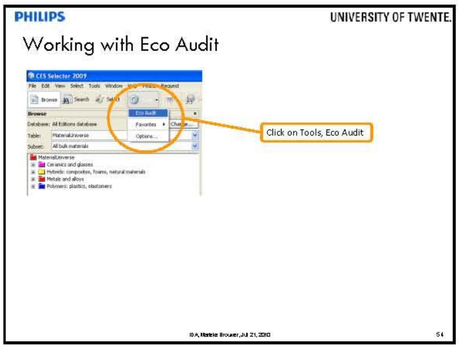
Configuration and objective	Configuration	Minimum volume: minimize	Minimum mass: minimize	Minimum embodied energy: minimize	Minimum material cost: minimize
Stiffness-limited design	Tie	$1/E$	ρ/E	$H_m\rho/E$	$C_m\rho/E$
	Beam	$1/E^{1/2}$	$\rho/E^{1/2}$	$H_m\rho/E^{1/2}$	$C_m\rho/E^{1/2}$
	Panel	$1/E^{1/3}$	$\rho/E^{1/3}$	$H_m\rho/E^{1/3}$	$C_m\rho/E^{1/3}$
Strength-limited design	Tie	$1/\sigma_y$	ρ/σ_y	$H_m\rho/\sigma_y$	$C_m\rho/\sigma_y$
	Beam	$1/\sigma_y^{2/3}$	$\rho/\sigma_y^{2/3}$	$H_m\rho/\sigma_y^{2/3}$	$C_m\rho/\sigma_y^{2/3}$
	Panel	$1/\sigma_y^{1/2}$	$\rho/\sigma_y^{1/2}$	$H_m\rho/\sigma_y^{1/2}$	$C_m\rho/\sigma_y^{1/2}$







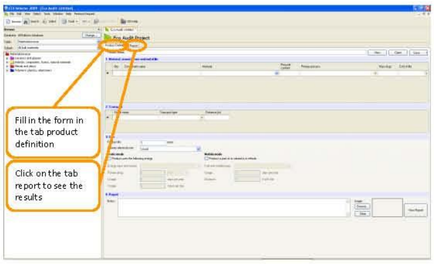




9

PHILIPS UNIVERSITY OF TWENTE.

Working with Eco Audit



©A,Marieke Brouwer, Jul 21, 2010 55

PHILIPS UNIVERSITY OF TWENTE.

6. Extra information and References

©A,Marieke Brouwer, Jul 21, 2010 56

PHILIPS UNIVERSITY OF TWENTE.

Extra information available at Philips

Books
- Material and the Environment, Ashby, M.
- Material selection in Mechanical Design, Ashby, M.

Internet
- www.grantadesign.com

Papers
- The Granta Eco Audit Tool – a white paper, Ashby M., Shoulter, P. e.a.
- The CES Eco Selector – background reading, Ashby, M., Miller, A. e.a.

Sheets
- Philips 001 – CES Training Course (All Editions).pdf

Report
- Sustainable Material Selection, Brouwer, M.T.

©A,Marieke Brouwer, Jul 21, 2010 57

PHILIPS UNIVERSITY OF TWENTE.

References

Books
- Material and the Environment, Ashby, M.
- Material selection in Mechanical Design, Ashby, M.

Papers
- The Granta Eco Audit Tool – a white paper, Ashby M., Shoulter, P. e.a.
- The CES Eco Selector – background reading, Ashby, M., Miller, A. e.a.

Sheets
- Philips 001 – CES Training Course (All Editions).pdf
- Sheets Course Materials, Hemmer, H. University of Twente

Report
- Sustainable Material Selection, Brouwer, M.T.

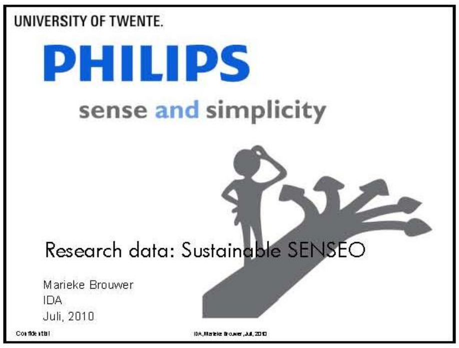
©A,Marieke Brouwer, Jul 21, 2010 58

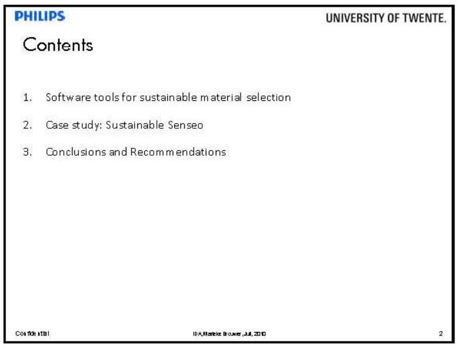
UNIVERSITY OF TWENTE.

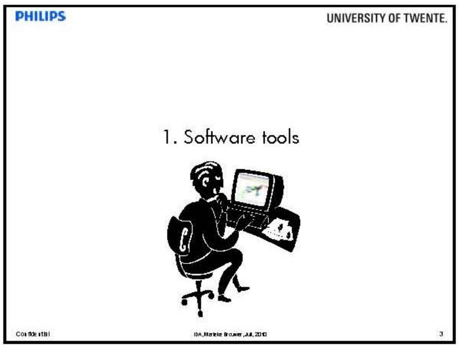
PHILIPS

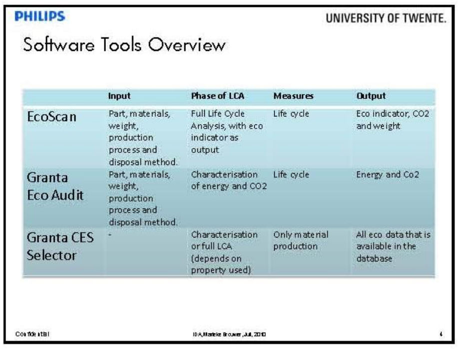
10

8. Sheets Research Data

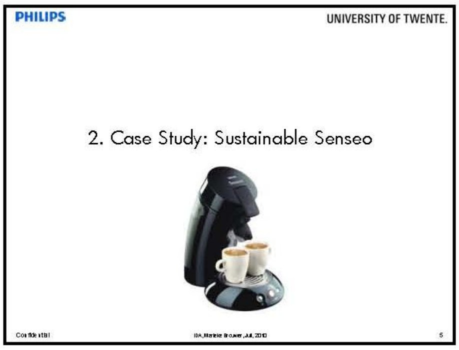


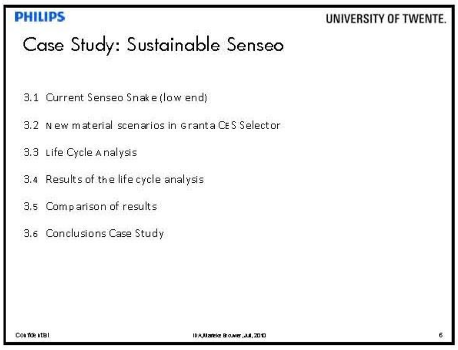




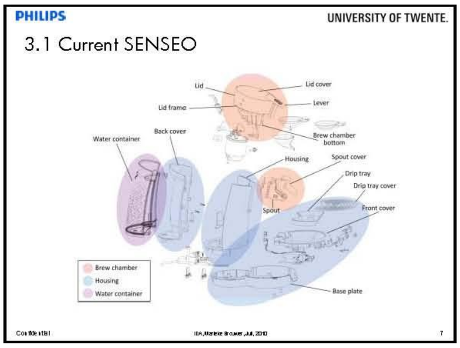


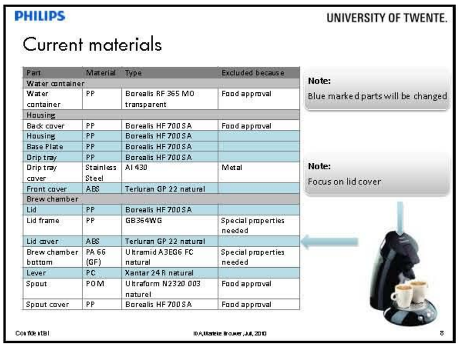
	Input	Phase of LCA	Measures	Output
EcoScan	Part, materials, weight, production process and disposal method.	Full Life Cycle Analysis, with eco indicator as output	Life cycle	Eco indicator, CO2 and weight
Granta Eco Audit	Part, materials, weight, production process and disposal method.	Characterisation of energy and CO2	Life cycle	Energy and Co2
Granta CES Selector	-	Characterisation or full LCA (depends on property used)	Only material production	All eco data that is available in the database



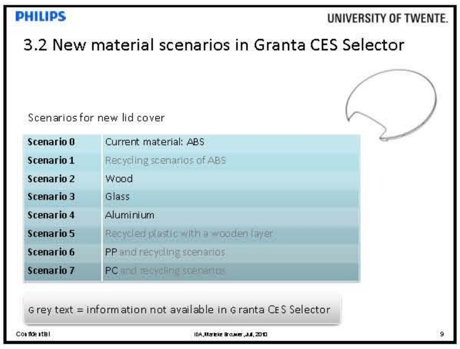


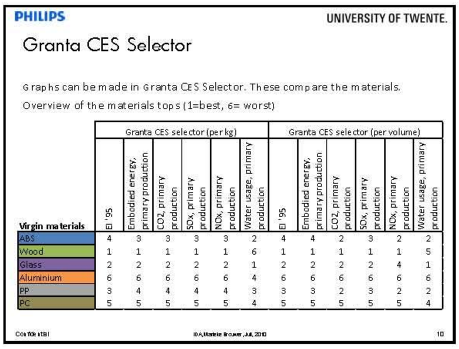
1



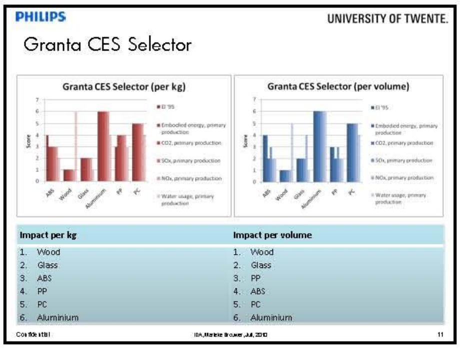


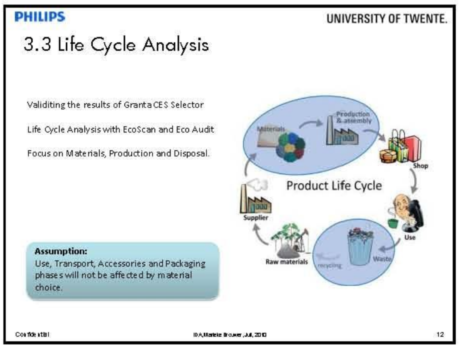
Part	Material	Type	Excluded because
Water container			
Water container	PP	Borealis RF 365 MO transparent	Food approval
Housing			
Back cover	PP	Borealis HF 700 SA	Food approval
Housing	PP	Borealis HF 700 SA	
Base Plate	PP	Borealis HF 700 SA	
Drip tray	PP	Borealis HF 700 SA	
Drip tray cover	Stainless Steel	AI 430	Metal
Front cover	ABS	Terluran GP 22 natural	
Brew chamber			
Lid	PP	Borealis HF 700 SA	
Lid frame	PP	GB364WG	Special properties needed
Lid cover	ABS	Terluran GP 22 natural	
Brew chamber bottom	PA 66 (GF)	Ultramid A3EG6 FC natural	Special properties needed
Lever	PC	Xantar 24 R natural	
Spout	POM	Ultraform N2320 003 naturel	Food approval
Spout cover	PP	Borealis HF 700 SA	Food approval





	Granta CES selector (per kg)						Granta CES selector (per volume)					
Virgin materials	EI '95	Embodied energy, primary production	CO2, primary production	SOx, primary production	NOx, primary production	Water usage, primary production	EI '95	Embodied energy, primary production	CO2, primary production	SOx, primary production	NOx, primary production	Water usage, primary production
ABS	4	3	3	3	3	2	4	4	2	3	2	2
Wood	1	1	1	1	1	6	1	1	1	1	1	5
Glass	2	2	2	2	2	1	2	2	2	2	4	1
Aluminium	6	6	6	6	6	4	6	6	6	6	6	6
PP	3	4	4	4	4	3	3	3	2	3	2	2
PC	5	5	5	5	5	4	5	5	5	5	5	4





Scenarios

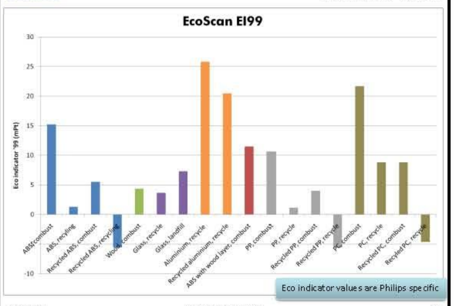
	Material	Density (kg/m³)	Mass of lid (g) (Volume: 35674.42 mm³)	Production process	Disposal
0	ABS	1040	37,1	Injection moulding	Incineration
1a	ABS	1040	37,1	Injection moulding	Recycling
1b	Recycled ABS	1040	37,1	Injection moulding	Incineration
1c	Recycled ABS	1040	37,1	Injection moulding	Recycling
2	Wood Coating	510	18,2 5,0	Pressing Spraying	Incineration
3a	Glass	2480	88,5	Pressing	Recycling
3b	Glass	2480	88,5	Pressing	Incineration
4a	Aluminium	2685	95,8	Casting & extrusion	Recycling
4b	Recycled aluminium	2685	95,8	Casting & extrusion	Recycling
5	2/3 Recycled ABS 1/3 Wood layer	1040 510	24,7 6,1	Injection moulding Adhere	Incineration
6a	PP	908	32,4	Injection moulding	Incineration
6b	PP	908	32,4	Injection moulding	Recycling
6c	Recycled PP	908	32,4	Injection moulding	Incineration
6d	Recycled PP	908	32,4	Injection moulding	Recycling
7a	PC	1200	42,8	Injection moulding	Incineration
7b	PC	1200	42,8	Injection moulding	Recycling
7c	Recycled PC	1200	42,8	Injection moulding	Incineration
7d	Recycled PC	1200	42,8	Injection moulding	Recycling

Confidential | IDA, Marieke Brouwer, Jul, 2010 | 13

3.4 Results of the life cycle analysis

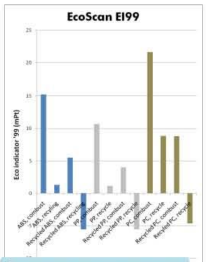
- EcoScan results on eco indicator
- Results indepth on eco indicator
- EcoScan results on CO2
- EcoAudit results on energy
- EcoAudit results on CO2

Confidential | IDA, Marieke Brouwer, Jul, 2010 | 14

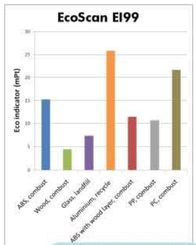


Eco indicator values are Philips specific

Confidential | IDA, Marieke Brouwer, Jul, 2010 | 15

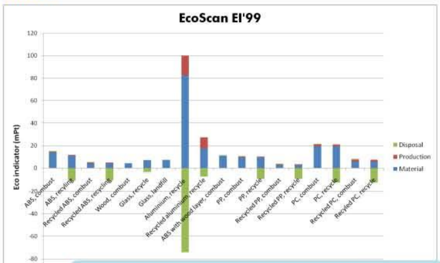


Recycling plastics shows the same trend



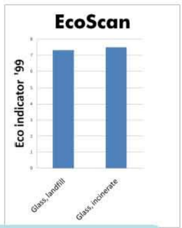
Same order of materials as the Granta CES Selector in graphs of eco indicator per volume

Confidential | IDA, Marieke Brouwer, Jul, 2010 | 16

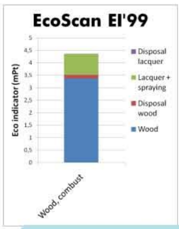


Production and disposal no big influence compared to material itself.
Disposal scenario for recycled plastics and virgin plastics, only one value, should be different as with aluminium

Confidential | IDA, Marieke Brouwer, Jul, 2010 | 17



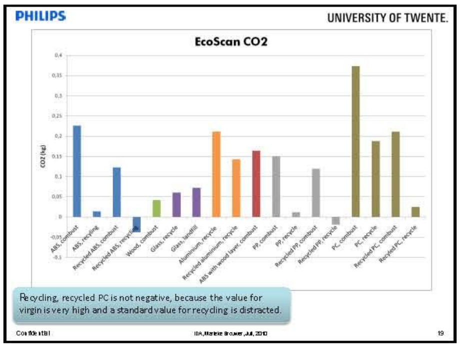
Eco Audit is not able to calculate the incineration of glass, in all graphs glass to landfill is used. This graph shows that it doesn't make a big difference

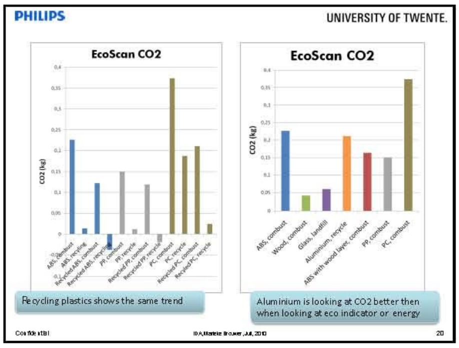


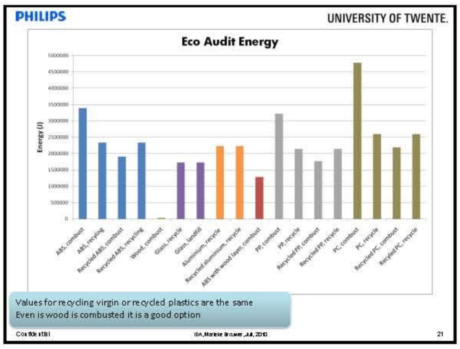
Lacquer accounts for 19% of the total environment impact of the wood scenario

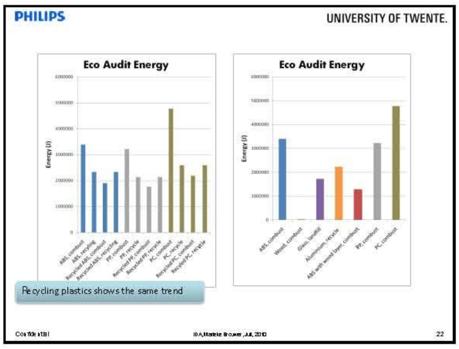
Confidential | IDA, Marieke Brouwer, Jul, 2010 | 18

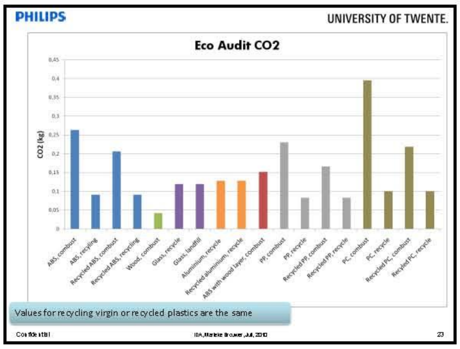
3

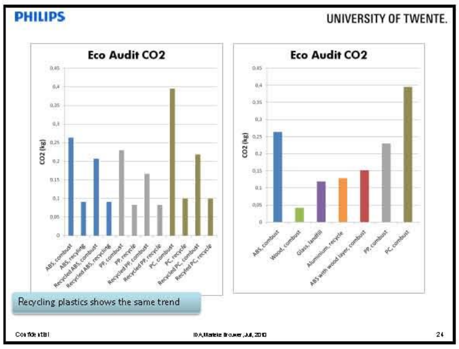

PHILIPS
UNIVERSITY OF TWENTE.
EcoScan CO2
Recycling, recycled PC is not negative, because the value for virgin is very high and a standard value for recycling is distracted.
Confidential
19


PHILIPS
UNIVERSITY OF TWENTE.
EcoScan CO2
EcoScan CO2
Recycling plastics shows the same trend
Aluminium is looking at CO2 better then when looking at eco indicator or energy
Confidential
20


PHILIPS
UNIVERSITY OF TWENTE.
Eco Audit Energy
Values for recycling virgin or recycled plastics are the same
Even is wood is combusted it is a good option
Confidential
21


PHILIPS
UNIVERSITY OF TWENTE.
Eco Audit Energy
Eco Audit Energy
Recycling plastics shows the same trend
Confidential
22


PHILIPS
UNIVERSITY OF TWENTE.
Eco Audit CO2
Values for recycling virgin or recycled plastics are the same
Confidential
23


PHILIPS
UNIVERSITY OF TWENTE.
Eco Audit CO2
Eco Audit CO2
Recycling plastics shows the same trend
Confidential
24

PHILIPS UNIVERSITY OF TWENTE.

Notes by graphs

Note Scenarios

a. An assumption is that the volume of the part will not change with the different materials. The mass will change, due to the density of the materials.
b. An assumption for scenario 5 is that 2/3 of the volume is plastic and 1/3 is wood.
c. All of the life cycle analyses are of one life cycle. If the material will be recycled several times the outcome may be different.
d. To calculate the wood impact Pinus Radiata is used.
e. To calculate the glass impact Borosilicate (Eco Audit) and White glass (EcoScan) is used.

Note EcoScan EI '99

f. To calculate recycled ABS 30% of the eco indicator of normal ABS is used. *
g. To calculate recycled PP 30% of the eco indicator of normal PP is used. *
h. To calculate recycled PC 30% of the eco indicator of normal PC is used. *
i. The wood production process in sawing, no extra production process is added in EcoScan. There are no values for solid wood pressing.
j. For the lacquer on the wood, the value for lacquer on plastic is used. There is no value for lacquer on wood, only on metal and plastic. Lacquer on plastic is worse than on metal, therefore plastic is chosen.
k. The PES 2007 database is used for the eco indicator values. Except for the recycled plastics.

Note EcoScan diversion of the values

In the values of glass and wood the values for material and disposal are altogether.

Confidential IDA, Marleke Brouwer, Jul, 2010 25

PHILIPS UNIVERSITY OF TWENTE.

Notes by graphs

Note EcoScan CO2

l. To calculate recycled ABS 30% of the CO² measure of normal ABS is used. *
m. To calculate recycled PP 30% of the CO² measure of normal PP is used. *
n. To calculate recycled PC 30% of the CO² measure of normal PC is used. *
o. The wood production process in sawing, no extra production process is added in EcoScan. There are no values for solid wood pressing.
p. For the lacquer on the wood, the value for lacquer on plastic is used. There is no value for lacquer on wood, only on metal and plastic. Lacquer on plastic is worse than on metal, therefore plastic is chosen.
q. The PES 2007 database is used for the CO2 values. Except for the recycled plastics.

Note Eco Audit Energy

r. For scenario 2, the production process used is assembly and construction. There are no other production processes available.
s. For scenario 2, no lacquer is applied. There is no value for lacquer in the database. Even with the 19% of the impact of lacquer included, wood will be the best choice.
t. There is used a typical percentage of recycled glass for scenario 3a and 3b.
u. For the values on aluminium an average aluminium type is used: A 356 T6.
v. For the recycled aluminium a typical percentage of recycled aluminium is used.

Note Eco Audit CO2

w. For scenario 2, the production process used is assembly and construction. There are no other production processes available.
x. For scenario 2, no lacquer is applied. There is no value for lacquer in the database.
y. There is used a typical percentage of recycled glass for scenario 3a and 3b.
z. For the values on aluminium an average aluminium type is used: A 356 T6.
aa. For the recycled aluminium a typical percentage of recycled aluminium is used.

Confidential IDA, Marleke Brouwer, Jul, 2010 26

PHILIPS UNIVERSITY OF TWENTE.

3.5 Comparison of results

- Granta CES Selector
- Percentages
- CO2 comparison

Confidential IDA, Marleke Brouwer, Jul, 2010 27

PHILIPS UNIVERSITY OF TWENTE.

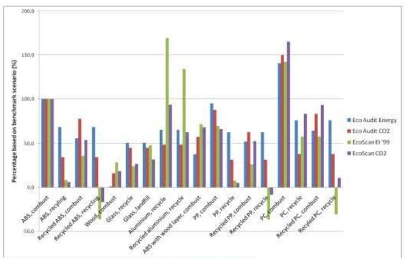
Granta CES Selector

- Graphs of eco indicator of virgin materials in EcoScan and graph in Granta CES Selector of eco indicator per volume show the same results.

Order of materials
1. Wood
2. Glass
3. PP
4. ABS
5. PC
6. Aluminium

Confidential IDA, Marleke Brouwer, Jul, 2010 28

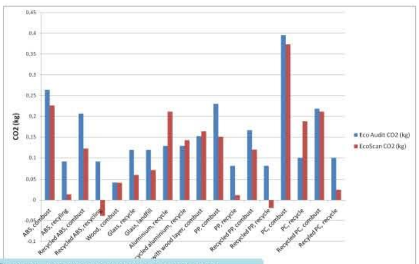
PHILIPS UNIVERSITY OF TWENTE.



Percentages are based on scenario 0 (ABS, combust) = 100%

Confidential IDA, Marleke Brouwer, Jul, 2010 29

PHILIPS UNIVERSITY OF TWENTE.



Results are different while measuring the same value

Confidential IDA, Marleke Brouwer, Jul, 2010 30

PHILIPS UNIVERSITY OF TWENTE.

3.6 Conclusions Case Study

1. Use as less different materials as possible. At the end of life there will be less waste streams needed to recycle the materials.
2. Use recycled materials. The best would be closed loop materials, because there will be taken care of the old Philips appliances. Using recycled materials is a good first step.
3. When looking at virgin materials as a substitute for plastics, use a fast growing wood or glass.
4. Make sure no toxic substances are used in the materials.
5. Think about the product, and work together with ARC, design, marketing, etc. The product needs to be sustainable, but also needs to be sold. Think about the benefits to the customer, for instance costs, appearance, attractiveness, usability, etc. A product that is made, but not used is not sustainable at all, it needs to fulfil a function.
6. Always keep the product life cycle in mind. Think about the changes in the product life cycle due to the material change:

- On weight of product: influence in transport
- On transport; make sure the new material doesn't need significantly more transporting.
- On processing: other processing = other impact
- On use: energy losses
- On volume: for engineering more or less material is needed for function.
- Disposal possibilities: not all materials can be recycled. The parts of the product need to be disassembled after use, this needs to be possible.

Confidential 31

PHILIPS UNIVERSITY OF TWENTE.

4. Conclusion and recommendations

Confidential 32

PHILIPS UNIVERSITY OF TWENTE.

Step-by-step plan

- A step-by-step plan is developed for selecting sustainable materials. This plan is explained (with case study) in the sheets: Sustainable Material Selection

Confidential 33

PHILIPS UNIVERSITY OF TWENTE.

General Conclusions

- Granta CES Selector is suitable in the earlier stages of the Philips product development process.
- Besides the information of the Granta CES Selector other things are important as well in selecting sustainable materials.
- For making well-founded choices, the step-by-step plan can be used.
- By using PP as a first material choice, Philips is on the right track. In some cases other materials like ABS and PC are only used because of the looks, this results in more waste streams, which is not good.
- Keep having contact with Design, Marketing and ARC. The product needs to be sold. When a product is made, but not used, it is not sustainable at all.

Confidential 34

UNIVERSITY OF TWENTE.

PHILIPS

6

9. Plan of approach

Bachelor assignment Philips – Sustainable material choices
Marieke Brouwer - S0139343

9.1 Index

9.2 Conceptual design

Actor analysis

Philips company and products

Philips is a global company. Originally it is founded in the Netherlands and still the design and engineering of many Philips products is done in the Netherlands. Through the years the company has grown and the list of products has grown with it. Nowadays Philips is still growing and changing. The focus now lies more on consumer electronics. In 2004 Philips unveiled its new brand promise of 'Sense and Simplicity' in products as well as the company. This includes the development of consumer products that are advanced, easy to use and designed to meet the needs of the consumers. The vision of Philips is focused on Health and Well-being.

Philips sustainability goals

Philips is set on health and well-being and one of the topics in this is driving health and well-being through sustainability. Within Philips sustainability is embedded at a corporate level and a part of the management agenda. Philips has its own sustainability programs for some time (EcoVision). Nowadays 30% of the total revenues are from Green products. The new EcoVision 5 sets the targets for 2015:

- 50% Green product sales
- Philips will bring care to more than 500 million people
- Philips will improve the **energy efficiency** of its overall portfolio by 50%
- Philips will double the global collection and recycling amounts of our products, as well as double the amount of recycled **materials** in our products

The way that should be done according to Philips is by focusing on three things: bringing care, improving the energy efficiency and closing the material loop.

Philips community

Philips is divided into several Sector. The sector located at Drachten is called Consumer Lifestyle. The Business Unit this project will be linked to is the Innovation Domestic Appliances (IDA). The domestic appliances are also divided into several innovation teams. These groups are: Water and Air, Floor care, Beverages, Shavers and Kitchen appliances. The project I will be working on is based in the Beverages department, where they are working on a sustainable Senseo. The information I will provide will be useful to the whole IDA community.

Project framework

Philips has had its own sustainability program for several years and since 2007 the targets for 2015 have increased considerably. Within IDA a number of projects, initiatives and requirements for sustainability have been worked on. A KWR project has started recently, in which the cooperation between Philips and Twente University on the field of sustainability is set. This project is located at Innovation Domestic Appliances.

Working on the sustainability of products, within Philips a lot is done on energy efficiency. The next step is to look at the materials of the product. Philips has bought the program Granta CES selector to use for the material choices in the designs and combine this software with the currently used Ecoscan. This program should be used to check if the current material used in products is sustainable and look at the alternatives. Philips wants to use trustful and recoverable materials in all Philips products.

A part of the IDA community now is working on a sustainable Senseo. Within this assignment this project will used as a benchmarking case.

Objective

The software program Granta CES selector has to be implemented in the IDA community. Therefore more familiarity with the program is necessary. In this assignment the possibilities of the Granta CES selector will be explored and the knowledge will be transferred to the IDA community.

The aim of the assignment is to set an example on sustainable material choices with the Granta CES selector. Hereby the sustainable Senseo will be used as a benchmark case. In the project the materials of the new Senseo have to be more sustainable. The verification of the material choices is very important.

The process can be divided into several steps. These steps are specified below.

<u>Building up knowledge.</u>

Research

- Acquainting with Philips Sustainability procedures
- Introduction to benchmarking product (Senseo, possibly also the Air purifier and Pitcher)
- Further indepth into Granta CES Selector

Material scenario build

- Explore and assess different materials choices for the benchmarking product (Senseo). Document ways of working with the programme for results, to contribute towards eventually recommending best ways of use.
- Working on Senseo, verification of the material choices. Focus on Senseo lid (possibly consequences of material choices on the design of the lid).

<u>Transfer of knowledge</u>

- Continue to work with Granta CES selector. When the Senseo benchmarking case does not give enough knowledge or if there is enough time, working on the other benchmarking products (Air purifier and Pitcher).
- Create a way of working with Granta CES selector for environmentally material choices that is suitable for the IDA community.
- Transfer of knowledge through a quick guide and a workshop for the IDA community. The documents will be available within Philips after the assignment, for future use.

Research questions

In this project questions need to be answered. The project is divided in three parts described in the objective. The questions fitting the part can be divided in main questions and sub questions.

<u>Research</u>

1. How does a Philips engineering team develop a (sustainable) product?
    - 1.1 What stages does a product go through before it is placed in the market?
    - 1.2 What are the Philips sustainability procedures (Ecoscan)?
        - 1.2.1 What are the possibilities of the Ecoscan software?
    - 1.3 In what stage(s) does the material choice develop?
    - 1.4 Who is responsible for the final material choice?
2. How can sustainability of materials be measured?
    - 2.1 What are the points of interest when looking at sustainable materials?
    - 2.2 How can these points of interest be measured?

3. How does the Granta CES selector work when looking at sustainability?
    3.1 What points of interest on sustainable materials are included in the Granta CES selector?
    3.2 How does Granta CES selector combine and measure these points of sustainability?
    3.3 What are the possible ways to use the software?

Material scenario build

4. How is the Senseo built?
    4.1 What materials is the Senseo builtfrom ?
    4.2 What properties do the materials used in the Senseo need to have?
5. How can Granta CES selector be used in the sustainable Senseo project?
    5.1 What are the targets for the sustainable Senseo?
    5.2 What material choices would be made for the project?
    5.3 Which information on materials brings Granta CES selector to the project?
    5.4 What material choices can be made based on the Granta CES selector?

Transfer of knowledge

6. How will a product engineer use the Granta CES selector without training on sustainable material selection?
7. How can Granta CES selector best be used in an IDA project team?
    7.1 What knowledge do the engineers have to have to be able to work with Granta CES selector?
    7.2 How can the use of Ecoscan and Granta CES selector be combined?
    7.3 In what part(s) of a project can Granta CES selector be used and what is preferable?
8. How can the knowledge of the Granta CES selector be transferred?
    8.1 What are the most interesting materials to use in sustainable products?
    8.2 How can the Granta CES selector be used in an IDA project team, to make sustainable material choices based on the way they are used to work?

Definition

KWR (Kenniswerkerregeling)

Financial arrangement within the scope of the economical crisis. Researchers of businesses will be attached to Universities and Technological institutes, this will be subsidized.

Granta CES selector

Software in with materials can be distinguished on their properties.

IDA

Innovation Domestic Appliances, part of the Philips Consumer Lifestyle Business.

Sustainability

Environmentally friendliness of products and materials for the total lifecycle and beyond.

Ecoscan

Currently used life cycle analysis software within the Philips IDA teams. Used for validation of Sustainable products.

9.3 Technical design

Strategy and material

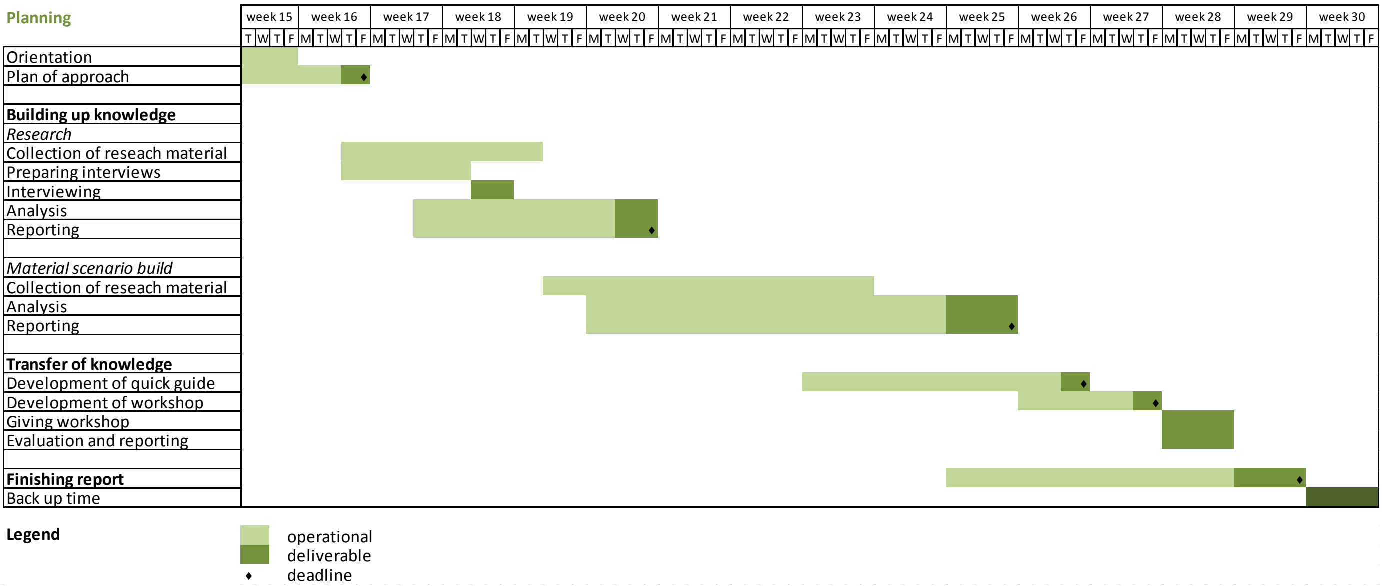
In the table below the strategy and the materials that should be used are stated per sub question. The people that will be interviewed will be defined later, when I have a clear view on the possibilities and on what is sensible.

Question	Strategy	Material	Opening up
1.1	Case study	People working at Philips	Interview
	Desk research	Documents	Analysis
1.2	Case study	People working at Philips	Interview
	Desk research	Documents	Analysis
1.3	Case study	People working at Philips	Interview
1.4	Case study	People working at Philips	Interview
2.1	Desk research	Literature	Analysis
2.2	Desk research	Literature	Analysis
3.1	Desk research	Documents	Analysis
	Case study	Reality	Observation*
3.2	Desk research	Documents	Analysis
	Case study	Person of Granta	Interview
3.3	Experiment	Reality	Observation*
	Desk research	Documents	Analysis
4.1	Case study	Senseo	Analysis and observation
	Desk research	Documents	Analysis
4.2	Desk research	Documents	Analysis
	Case study	People working at Philips	Interview
5.1	Desk research	Documents	Analysis
	Case study	People working at Philips	Interview
5.2	Case study	People working at Philips	Interview
5.3	Case study	Reality	Observation*
5.4	Case study	Reality	Observation*
6	Experiment	People working at Philips	Observation (in workshop)
7.1	Desk research	Literature	Analysis
	Case study	Reality	Observation*
7.2	Formulation of a theory	Reality	Analysis

* Trial with software

Planning

Below a chart of the planning is shown. For the full view, see *Marieke Brouwer BaO Planning.xlsx*



<u>Bottlenecks and possible solutions</u>

The possible bottlenecks of this project are: the benchmarking product, the time, the people and chronologies.

- The benchmarking product can be not suitable enough as a benchmark to choose sustainable materials. Therefore there are defined two other product which can be used (air purifier and pitcher).
- The timing in this project can get very tight. Working with a planning in which the activities are overlapping I hope to get the project done in time.
- The Shrek project has its own planning that may be difficult to align with my project.
- The people I need to interview have to have time to do this interview. If it is not possible to have the interviews in week 18 I will have to start earlier with the material scenario build, so I will have some time in that part of the planning to do the interviews. Fortunately these parts do not have to be done chronological. The interviews have the most influence on the first main question.
- The chronology of the questions is chosen consciously. The first six main questions can be answered in a different order, but they are all needed to answer the last two questions.

9.4 Annex

Report introductory talk

At March 26th I went to Philips in Drachten to meet with Erica Purvis and Mark-Olof Dirksen. This meeting was meant to get to know each other and to get some information about the project.

First we did a little introduction. They told about themselves and I told about myself. They already received my CV so we talked about that. I told them about the set up of the sustainability course at the university and about my knowledge about CES and sustainability. Erica and Mark-Olof could get an image of what I know and what I can do for Philips.

Erica told me about the company. How it is set up and what happens in Drachten. She gave me a tour in the building.

After this meeting we didn't define an assignment. We agreed that Erica and Mark-Olof would discuss the assignment and then send it to me. I could change it if I want to. The contracts will be arranged later.

Description of the assignment by Philips

See *Student assignment – CES selector.docx*

References

http://www.uu.nl/NL/onderzoek/Onderzoekenmaatschappij/Pages/Kenniswerkersregeling.aspx, 12th April 2010, Universiteit Utrecht.

http://www.philips.com, 16th April 2010, Philips

Veen, T. van, Powerpoint Presentation: Workshop recycled materials, 13 & 14 April 2010, Sustainability Centre Consumer Lifestyle.