

Design of Products with Recycled Plastics: Towards a Design Aid

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Abstract

The increasing amounts of plastics waste over the last decades, has given an incentive to recycle more material into new products. This is in line with the prevailing ecodesign strategies developed in academia today. This paper tries to bridge the gap between these strategies and the actual knowledge needed by students and designers in general to carry these out in their design projects. The paper presents a set of enablers and constraints to be considered when designing products with recycled plastics. It is believed that such an overview will make existing knowledge more easily accessible, and stimulate the use of recycled plastics in design.

1 Introduction

In the past decade, environmentally conscious design (or ecodesign) has gradually started to play a substantial role in industrial design and design engineering curricula around the world. Partly, this takes place in separate courses, but partly (and increasingly) also integrated within 'regular' design and engineering courses. Within the broad discipline of ecodesign, a wide range of topics are taught. At both Delft University of Technology (DUT) and the Norwegian Institute of Science and Technology (NTNU) for example, aspects of ecodesign that are taught in various courses include basic environmental sciences, application of sustainable materials and technologies in product design, knowledge about ecodesign in industrial contexts, and environmental assessment of products and services. Such courses explicitly address many aspects of ecodesign, and aim to make students aware of opportunities and challenges that exist in sustainable product design. This information is then applied, explicitly or implicitly, in various other traditional courses, both on the Bachelor and the Master level. In these courses, students usually show increased awareness and interest in sustainability issues.

Especially in courses where students are to apply the theoretic knowledge presented to them into design or product development projects, often questions on the operationalisation of ecodesign need to be addressed. One type of questions that increasingly often emerge is related to the application of recycled plastics in products; how can we make sure our products are recyclable? And: how can we start using recycled materials? Whereas until now, it has not

seen many eco-efficient applications, the use of recycled plastics is becoming an increasingly feasible alternative to be considered in eco(re)design. This observation is motivated by the presence of increasingly larger volumes of plastics in life-cycles of products [1], increasingly more sophisticated collection systems, consequently maturing markets for secondary plastics, and increasing knowledge on how to apply recycled plastics as described by Hulse [2] which is also demonstrated by the increasing number of companies active in this field, offering plastics compounds based on both post-industrial and post-consumer waste. Hence, it is likely that the demand for knowledge on how to design with recycled plastics will increase as well. However, for design students, very limited information on this subject exists, which should be improved in order to guarantee that they will consider using recycled plastics when an opportunity for doing so manifests itself.

This paper addresses the question what minimum level of information students will need to make motivated judgements, and in what way this information should be passed on to them. The paper is outlined as follows; Section 2 will give a short review of the role of using recycled plastics in existing ecodesign methodologies, and conclude with a problem statement. Section 3, describes the wants, needs and the lack of tools to consider applying of recycled plastics in products. In section 4 a list of requirements towards a design aid for design with recycled plastics is presented, showing the enablers and the conditions for using recycled plastics in product development are presented. Section 5 contains a discussion and concluding remarks with respect to the design aid.

2 The role of recycled plastics in eco-design methodology

Students at both NTNU and DUT are taught various ecodesign methodologies and tools. One well-known tool is the so-called LiDS Ecodesign Strategy Wheel, which originates from the Promise Ecodesign Manual [3], which is probably one of the best known ecodesign manuals globally.

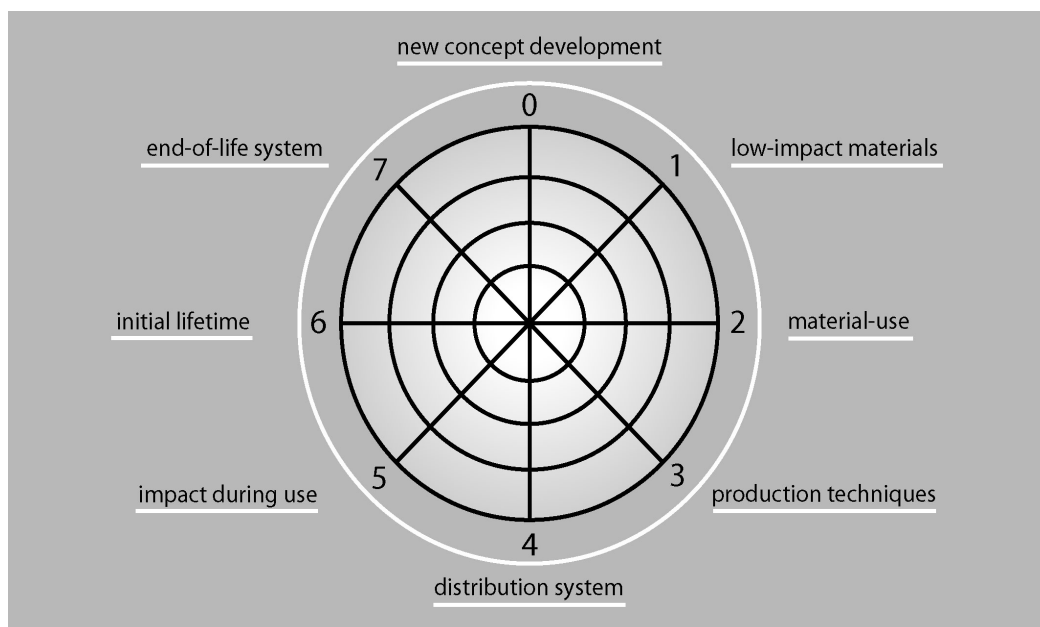


Figure 9. The LiDS Ecodesign Strategy Wheel

The LiDS Wheel is designed to help designers find environmental improvement options when (re)designing products. On a product level, the wheel can be regarded as a useful tool to map the environmental issues and potential directions for improvement. However, as is common

for most ecodesign tools and methodologies, it does not provide much practical information, nor does it give an operationalisation of some crucial ecodesign concepts. For example, 'selection of low-impact materials' is, on a product component level, the first mentioned ecodesign strategy, which includes among others the use of recycled materials.

2.1 The rationale for using recycled plastics

The rationale for including the use of recycled plastics in ecodesign methodologies is clear. Our society has become dependent of plastics over the last decades and as for the use of plastics, the amounts of waste are increasing as well. In many products, packaging being the largest sector, the product has a very short lifetime and rapidly becomes waste. The alternative waste management paths for plastics are;

- (i) Mechanical recycling, where the materials are processed and made into new products and hence saving the production and polymerisation of virgin material.
- (ii) Feedstock recycling, plastics are broken down into monomers or other feedstock.
- (iii) Incineration, with or without recovery of energy.
- (iv) Landfill, which usually is the least desirable option, either because of environmental factors or waste management issues.

When talking about recycling of plastics in this paper we focus on the mechanical recycling of plastics. The amount of mechanical recycling in Europe is increasing rapidly. In 2003, 14.8 % of the total plastics waste was mechanically recycled, exceeding the 11 % potential from post-user plastics estimated by TNO [2]. Dependent on the source of material, for example industrial scrap or a mixed plastic stream from the municipalities, the material has to be collected, sorted, cleaned and processed. An impure or polluted stream of plastics will result in lower mechanical properties in the new material. Hence, the material quality that is produced by the recyclers and the availability of material is key issues to be addressed for designers opting for a more sustainable material choice. The use of recycled materials could also affect the production and product lifetime; therefore it is important those designers are able to make these considerations.

Going back to the LiDS wheel and the Promise Ecodesign Manual, they provide a number of rules-of-thumb, of which the following (can) relate to the use of recycled plastics:

- Use recycled materials wherever possible, to increase the market demand for recycled materials
- Use recycled plastics for the inner parts of products which have only a supportive function and do not require a high mechanical, hygienic or tolerance quality.
- When hygiene is important (as in coffee cups and some packaging) a laminate can be applied, the centre of which is made from recycled plastic, covered with or surrounded by virgin plastic.
- Make use of the unique features (such as variations in colour and texture) of recycled materials in the design process.

Although rules-of-thumb like this can already stimulate the creativity of designers, in general they provide little information to aid designers in their product development. This is true for other ecodesign methodologies as well. Tischner et al. [4] mention the use of recyclable materials as part of one of the highlighted ecodesign strategies (Selection of low-impact materials), but do not operationalise this beyond a very rough statement that the input of 100% recycled plastics/paper/cardboard reduces environmental loads in comparison to the input of virgin plastics/paper/cardboard by 40%. In the Eco-products directory 2004, a

comprehensive guide for those wanting to get inspired for doing ecodesign [5], a number of recycled plastics to consider in ecodesign are mentioned, but again, such general statements do not provide enough (or any for that matter) information for designers to consider the use of recycled plastic.

2.2 Problem statement and research objective

To summarize, based on experiences in the above mentioned courses, it has become clear that students are in need for information on how to design products with recycled materials as existing tools and methodologies might refer to the use of recycled or secondary materials as a preferred design strategy, but with only limited practical applicability. Guidance to practically work with recommendations to use recycled plastics in design projects mostly remains on a generic level without ways to make this specific to one particular design problem. Based on these considerations, the following research objectives were chosen:

- How to extend existing ecodesign methodologies with practical information on how to design with recycled plastics?
- From a designer's perspective, which variables play a role when considering recycled plastics?

Given the fact that the scope of the research is on a fairly elementary level, i.e. students in design and engineering disciplines, the last sub-questions are posed as:

- What are meaningful levels of information for each variable that are sufficient to address elementary redesign problems?
- How should this information be communicated to designers and engineers in a way that would simplify their effort to use recycled plastics in detailed product design?

A further scoping of the research objective is that the use of recycled plastics will be discussed in the context of mass-produced applications in consumer goods. This typically applies for packaging applications (such as in shampoo bottles or crates) and applications of parts in products, which can be chairs, electronics, etc.

3 Identification of Wants and Needs related to design with recycled materials

The Promise Eco-design manual assists the student/designer further by elaborating on the material choice by the following prioritizing; 1) Try to use recycled materials, 2) Make your product recyclable and if (1) and (2) are not possible you should make sure your material has a proper end-of-life treatment. So, what *is* actually the level of information that designers need in order to be able to seriously consider using recycled materials in their design projects? A study in the UK [6] has listed the problems that designers face when selecting recycled materials and products, which highlights the points made in the current paper. It shows that although designers do actually specify the use of recycled products and materials (50% say less than one quarter of the time, whereas another 35% says never, and 15% half or more of the time), they experience major obstacles in doing so. The major obstacles found in this study are:

1. Lack of information; several types of information are lacking, such as 1) What recycled products and materials is available 2) Technical product-material information, 3) The environmental credentials of recycled products and materials.

2. Supply issues; Designers encounter difficulties both in locating suppliers of recycled products and materials, and then obtaining a reliable supply with proper product information.
3. Quality; the quality of recycled products and materials may not be as good as that of non-recycled. Moreover, there is a clear informant concern over a lack of accreditation for recycled materials
4. Unfamiliarity; hence, designers may play safe. Also, suppliers need to be informed
5. Cost; recycled products and materials might be more expensive than non-recycled ones. In those cases, consumers are unlikely to be willing to pay a premium to use recycled products
6. Practical constraints; (starting to) using recycled plastics involves a greater time commitment; moreover it increases designer liability

The recommendations made in this study, addressing the UK government, include the promotion and improving understanding of the potential uses of recycled materials, development of improved quality in and standards for recycled materials, and stabilisation of markets for recycled materials.

Most of the above findings are reflected in experiences with ecodesign education at both mentioned universities, although some concerns such as the cost issue might have improved since. Combining the above findings with practical experiences in courses at NTNU and DUT, in the next chapter a list of requirements for a design aid for consideration of recycled plastics is proposed in Tables 1 and 2. These requirements are separated in content-based requirements and format-based requirements. Content-based requirements address in general address facts and numbers, whereas format-based requirements address the way content is presented. In many cases, required content can be both in the form of static and dynamic information. Furthermore, in communication with students it is relevant to distinguish between principles and actual content. In many cases, students should not be supplied with facts (such as: plastic polymer X is only limited available with fixed specifications), but with the insight that they need to check availability in relation to specifications for a certain plastic type and application.

One of the decisions to be made in developing such a design aid is how to balance the amount of fixed content (given the fact that much of the information is dynamic and/or incomplete) with information how to obtain content that is not present in the design aid itself.

4 Toward a design aid for design with recycled plastics

In order to stimulate appropriate application of recycled plastics in products, design students should first be able to recognize a possibility to do so. Secondly, whenever a possibility is recognized, students should be able to determine what type of recycled plastic would best fulfill the specifications in a certain design problem. It makes sense to address both stages in a design process from the perspective of *enablers* and *constraints*.

In Tables 1 and 2, the enablers and constraints for use of recycled plastics are presented in more detail. In these tables:

- The first column shows the enablers and constraints for using/not using recycled polymers in products.
- The second column discusses what relevant facts need to be assessed and what the relevant indicators are.

- The third column gives thought to how design students should acquire and interpret this information.

4.1 Enablers for using recycled plastics

In order to recognize a possibility to use recycled plastics, students should become aware that various enablers exist that might create the option for feasible application. These can be of the following nature:

- Economical; for example, recycled plastics are often up to 50% cheaper than virgin plastics.
- Environmental; for example, use of recycled plastics will reduce the need for virgin plastics, in many environmental evaluations this will show up as a positive effect. Companies in search of options for reducing environmental impacts of their products might thus benefit from such applications.
- Image related; for example, companies in search of ways to show their commitment to environmental goals might actively look for ways to communicate their efforts. Being able to demonstrate this with use of recycled plastics may thus be beneficial.
- Legislation based; for example, companies looking for ways to increase the recyclability of their products (for example because of the WEEE directive) might benefit from the use of recycled plastics as in many evaluation schemes, the use of recycled plastics will count positive towards recyclability targets.

4.2 Constraints against using recycled plastics

Once a possibility to use recycled plastics is recognized, the next step is to be able to select a particular type of recycled plastic by determining whether this type fulfills the specifications of the design problem. In design problems in general, design students will often use material databases, like CES or Idemat, or consult with a material scientist. Material databases are able to show how different materials fulfill a needed set of properties, and in some cases they will present a range of materials that fulfill a certain set of required properties.

In the context of recycled plastics, most material databases will not be up-to-date with information on recycled plastics, which may in many cases also be true for material scientists in general. In order for students to be able to determine themselves the feasibility of application of recycled plastics, it is necessary to make them aware that there are various constraints, in some cases specifically linked to recycled plastics that will determine feasibility. These constraints can include required material properties, aesthetic properties, economic factors, legislation prohibiting the use of recycled plastics, and supply chain issues.

Table 1. Enablers behind the use of recycled polymers

<p>Learning goal <i>Enablers for using/ not using recycled polymers in products</i></p>	<p>Content-based requirements <i>What is the relevant information that needs to be assessed and what are the relevant indicators</i></p>	<p>Format-based requirements <i>How can students/designers acquire and interpret this information</i></p>
<p>Students/Designers should be aware of the possible environmental benefits that may arise from using recycled plastics.</p>	<p>Information about the environmental impact of recycled plastics and the virgin alternative. Oil and gas are the raw material when producing polymers, and the energy use [MJ] is therefore a central characteristic with respect to environmental performance.</p>	<p>Sources of information are LCAs and material specific studies. Students should be able to find the environmental impact of recycled plastics in relation to alternatives. Students should be able to track the environmental impact of recycled plastics in case these are not supplied by the design aid. However, in practice one might assume the environmental impacts of recycled materials to be lower than virgin, even for mixed plastics waste.</p>
<p>Students/Designers should look for the possibility of saving production costs by using recycled materials.</p>	<p>Information about the price of recycled plastics and the virgin price. For the mass production the material purchasing costs [€] is an important feature. The prices of recycled polymers are dependent on the polymer and its market, but are usually much lower than the virgin material. For polyolefins the recycled material is approximately 50 – 70 % of the virgin material price.</p>	<p>The information need to be collected from the supplier or market place. Recycled material is cheaper than virgin material but students should be careful when comparing a virgin material with a recycled which origins from different qualities. The more control the recyclers have on the material properties the higher the price will be. Some firms sell recycled packaging material for 50 – 60 % of virgin price¹, while for other recyclates that have a more comprehensive product declaration this is around 80%².</p>
<p>Students/Designers should be aware of the effect that using recycled material in their product will have on product and company image.</p>	<p>Information about consumer values and preferences. If environmental performance is important for the consumers of the product it might have a positive effect on the market share.</p>	<p>Design students could investigate the preferences of possible consumers if they consider this aspect a selling point. Students should be able to assess the consequences for consumer appreciation of use of recycled plastics.</p>
<p>Students/Designers should become aware that legislative developments can stimulate or hamper the use of recycled plastics.</p>	<p>Information about legislation related to recycled plastics, product category, and legislation that gives an incentive for using recycled material.</p>	<p>Students should be able to find the most relevant legislation applicable to recycled plastics.</p>

¹ According to information from Swedish recyclers Plaståtervinning and Plastic Recycling.

² According to Dutch recycler AKG.

Table 2. Constraints for the use of recycled polymers

<p>Learning goal <i>Constraints for using/not using recycled polymers in products</i></p>	<p>Content-based requirements <i>What are the relevant facts that need to be assessed and what are the relevant indicators?</i></p>	<p>Format-based requirements <i>How can students/designers acquire and interpret this information?</i></p>
<p>Students/Designers should understand the vital material properties of a polymer that affects their product performance.</p>	<p>The adequate information about material properties depends on the product as for using virgin qualities; Impact strength, Elongation, Young's modulus etc. In addition, a producer of recycled material might not be able to produce the same material quality in each batch.</p>	<p>Information about material properties should be given by the material supplier on product declaration sheets. Serious suppliers should be able to give a number of material properties to ensure consistency in material quality. The properties may have been affected by the recovery process, the material purity or lack of stabilization. The recycler should also be able to add stabilizer if this is needed.</p>
<p>Students/Designers should become aware that the aesthetic properties of recycled plastics may differ from primary plastics.</p>	<p>General aesthetic information about recycled plastics, mainly colors, gloss, and surface properties.</p>	<p>Information given from supplier to be able to determine the aesthetic properties of recycled plastics, and the supplier's possibility to add for example color master batches. Examples using pictures will be important to create a feeling of what is (im)possible.</p>
<p>Students/Designers should be aware of how the economics and marketing will be affected, together with product development.</p>	<p>Information about how owners and consumers perceive the risk of using a different material. Information about consistency in material quality.</p>	<p>Gather information on owners and customers view on using a recycled material. Production processes might have to be adjusted due to change of material, is the production able to handle slight fluctuations in material quality during the year? Students should be able to assess the consequences for other aspects of product developments besides design and manufacturing.</p>
<p>Students/Designers should look into any product specific legislation limiting the use of recycled polymers.</p>	<p>Regional and local legislation. Students should be able to determine what information is relevant to their design problem.</p>	<p>Information available in EU legislation such as the Packaging directive and WEEE directive, and country specific legislation. Recycled plastics are not suitable for products with for example food contact and medical applications.</p>
<p>Students/Designers should be aware of the history of the recycled material.</p>	<p>Information about what was the previous application of the material, and what additives is it likely to content.</p>	<p>Suppliers can give information if they are using industry scrap or separated plastics waste from the municipalities as raw material.</p>
<p>Students/Designers should become aware of the importance of their supply chain and that it may not be possible to generate all information they need.</p>	<p>Information to identify the relevant actors of the suppliers of a certain recycled plastics will yield the history of the material, continuity of supply and specifications of material properties</p>	<p>Students need to be able to estimate the likelihood of obtaining the level of detail of information they need and to assess the consequences of not being able to do so. They also need to be able to make motivated decisions about the consequences of this lack of information for their design.</p>

5 Discussion and conclusions

Both literature and practical experiences teach us that designers, and in particular students becoming designers, require information to be able to translate strategies given in the ecodesign methodology into concrete design actions. This paper has illuminated the most important issues that need to be addressed when trying to design products with recycled material, or more specific recycled plastics. As these issues will depend from design problem to design problem, it is not desirable to give more than generic advice on these issues; the paper deals with issues that might arise during a design process, and points to sources where this information can be obtained. These issues may be a step towards a design aid for using recycled plastics, and/or extension of existing ecodesign methodologies. Once this information is properly embedded, it will become possible to improve both

- the number of times that the use of recycled plastics in design projects is considered by students and designers in general.
- the level of success of application of recycled plastics in design projects.

Hopefully these improvements/suggestions will contribute in increased awareness among students and designers, and provide an incentive to consider applying recycled plastics in their products design.

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