Quality assessment and estimation of substitution ratios for recycled plastic

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Introduction: Plastic and life cycle assessment (LCA) of plastic recycling

Due to desirable properties, such as durability, low weight and low costs, the consumption of plastic has increased tremendously the last half century. As a result, the generation of plastic waste has increased as well.

Plastic is almost exclusively produced from fossil resources. Consequently, recycling of plastic waste has gained public attention, as a measure to save fossil resources and reduce environmental impacts from treatment of plastic waste.

However, plastic waste is often a very heterogeneous material, including items of different polymer types, colours, rigidity, etc. The heterogeneous nature of plastic waste is a challenge for recycling and it might result in reduced qualities of the raw materials produced. This may affect the environmental performance of plastic recycling systems, and it is therefore important to model the systems accurately, when evaluating their environmental performance.

The environmental performance of plastic recycling can be evaluated using LCA, setting up a system like the one in Figure 1.

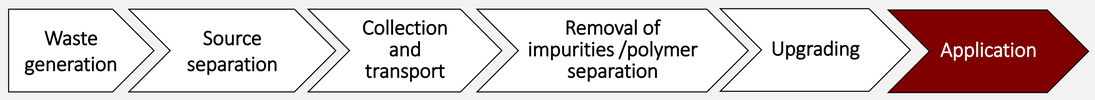


Figure 1: Processes included in an LCA of a plastic recycling system. A substitution ratio needs to be included at the application stage

Recycling is credited by subtracting the environmental impacts from the virgin material assumed substituted by the recycled material produced.
→ Important to include a ***substitution ratio (SR)*** (Between 0 and 1)

SRs from market mechanisms (actual substitution) or quality difference.
→ No consensus. Need for a consistent and transparent way to estimate SRs.

Objectives

The objectives are to assess parameters important for the ***quality***, measured as the applicability, of recycled plastic, compared to virgin plastic, and on that basis evaluate ***substitution ratios for recycled plastic*** from industrial plastic waste and plastic waste from households.

Focus on:
- Applicability and ***possible*** substitution rather than actual substitution
- PET, HDPE, LDPE, PP and PS
- European conditions
- Mechanical recycling

Parameters crucial for applicability: Functionality

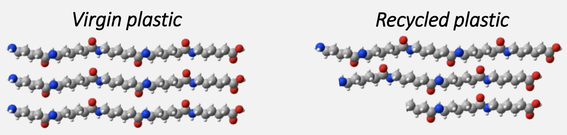
The functionality of the recycled plastic is crucial when it comes to what kinds of applications the recycled plastic can be used within.

Main factors influencing functionality:

- *Polymer cross-contamination*

Too high content of unwanted polymer
→ compatibilization is necessary

- *Length of polymers in recycled plastic*

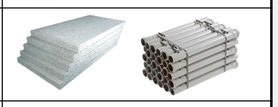


Different polymer lengths
→ problems for processing

Parameters crucial for the applicability: Legislation

Complying with legislation is essential when identifying what applications recycled plastic can be used within.

Table 1: Legislative requirements for the chemical composition of plastic for relevant applications

Application	Comprehensiveness of legislation*	Requirements	Example of products
Food packaging (FP)	High	Migration limits	
Toys (T+T36)	High	Total limits and migration limits	
Electrical and electronics (EE)	Medium	Total limits	
Pharmaceuticals (PH)	Low	Labelling of CMR classified phthalates	
Building and construction (BC)	Low	Labelling of certain chemical substances	
Non-food packaging (NFP)	-	*No* specific legal requirements	
Automotive (AU)	-	*No* specific legal requirements	
Others (OT)	-	*No* specific legal requirements	

* Comprehensiveness of legislation indicates the number of substances included in the legislation

Market shares of applications

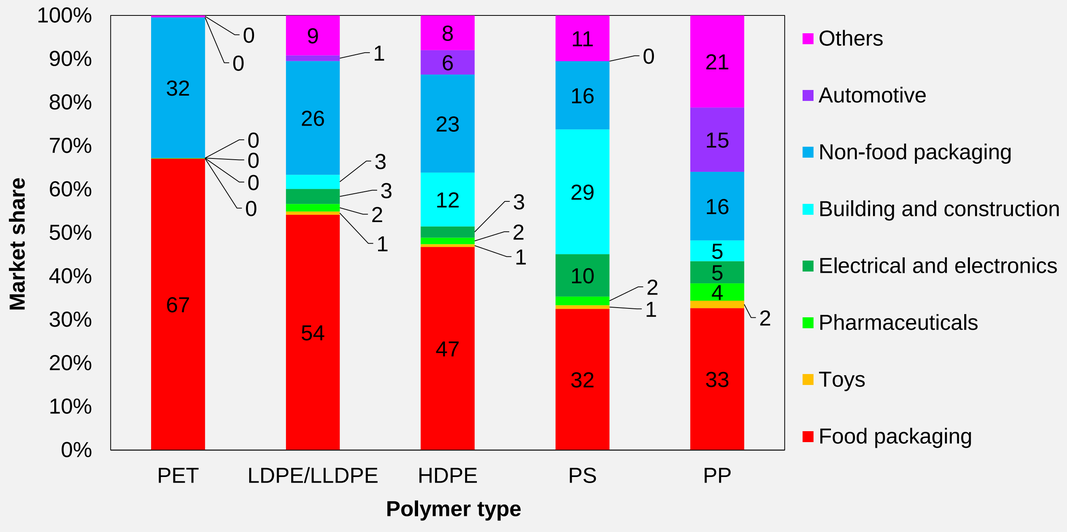


Figure 2: Market shares of the different applications on the individual polymer markets are used to weight the importance of use within the different applications to the quality of recycled plastic.

Preliminary results

Table 2: Substitution ratios (illustrating the share of the market in which the recycled plastic has the possibility to substitute virgin plastic) for recycled plastic allowed in food packaging and recycled plastic not allowed for use in food packaging. IW: industrial waste. HHW: Household waste. FP: Food packaging

	Use in FP allowed		Use in FP *not* allowed	
Polymer	IW	HHW	IW	HHW
PET	1	1[a]	0.33	0.33
HDPE	-	-	0.49-0.51	0.49-0.51
LDPE/LLDPE	-	-	0.40-0.45	0.40-0.44
PP	1	-	0.61-0.66	0.57-0.62
PS	1	-[b]	0.55-0.65	-[b]

[a] HHW sample from homogeneous waste stream of PET bottles
[b] No PS samples from HHW were assessed

- Complying with ***legal requirements*** and having the necessary ***functionality*** are crucial parameters for the applicability and quality of recycled plastic.
- The market share for food packaging is dominating for all five polymer markets.
- Recycled plastic from household waste can most often not be used for food packaging → Low quality
- Recycled plastic from industrial waste were of both high and low quality

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