STRIVING FOR EFFICIENCY: OPTIMUM VS. MAXIMUM RECYCLING TARGETS

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Abstract

Recycling targets are an important and useful means to optimize waste management. They have been fixed for a variety of waste streams such as household waste, packaging waste, construction and demolition waste. The effective recycling rates differ considerably with respect to materials and among EU members and range from virtually zero to 80% and more. For instance, high rates are achieved for wastepaper and waste glass; for other materials such as scarce metals, the rates are sometimes below 1%. Therefore, improvement must tend towards higher recycling rates and targets, and this is what can be seen when the development of recycling targets over time is observed. However, 100% recycling is not feasible and recycling targets close to 100% would require major efforts, causing detrimental overall effects. It is therefore instrumental to determine optimal recycling targets that maximally contribute to achieving waste management goals, thereby protecting humans and the environment and furthering the conservation of resources. This chapter provides an example of how the optimal recycling target can be determined and discusses the problems associated with ascertaining such targets, which an analysis of the example brings to light. Findings indicate that the determination of the optimal recycling rate is a complex task that requires information (data) that is currently not fully available. It is also a permanent task as the optimal recycling rate is a moving target which is dependent on commodity prices, product and technology developments.

Introduction

Recycling is a major means to realize the ecological goals of waste management, namely, *to protect men and the environment* and *to contribute to resource conservation*. The metabolism of modern industrial societies is characterized by increasing anthropogenic stocks and a rather linear use of materials. Except for selected wastes such as paper and glass, recycling loops still play a minor role. Changing this is a major goal of the circular economy model. In order to stimulate materials recycling, decision makers have employed recycling targets, which have become increasingly ambitious over the years. It may be reasonable to increase such a target from 30 to 40%, but it is less clear if this also holds for the step from, say, 75 to 85%. What is known for sure is that 100% recycling is not feasible due to natural constraints and that recycling close to 100% requires unjustifiable efforts. Keeping this in mind, it becomes clear that there must be an optimal recycling rate, which is, at first, not known and must yet be determined.

To our knowledge, there are not many studies which focus on finding the optimal recycling rate for a waste category. However, there has been some work on end-of-life vehicles (van Shaik & Reuter 2004) and waste electronic equipment in general (Huisman et al. 2001, Oswald 2013). In the following, we summarize a study by Laner & Rechberger (2007) on cooling appliances, where a methodological approach for the determination of the optimal recycling rate was outlined. The purpose of that study was to demonstrate generally relevant contextual information when attempting to determine an optimal rate. Cooling appliances here only serve as a case study and the numerical results of the study are probably no longer valid, which is in the nature of things, as will be shown later.

Case study: Recycling of cooling appliances

The above-mentioned study was performed to find out the optimal recycling rate for cooling appliances. The motivation was a then new ordinance on Waste Prevention, Collection and Treatment of Waste Electrical and Electronic Equipment, which fixed the minimum recycling rate for cooling appliances at 75%. The aim was also to find out whether this higher recycling target would lead to better treatment practices for cooling appliances with respect to resource recovery and environmental protection. For this purpose different treatment technologies, which achieved recycling rates of between 50 to 90%, were compared both for cooling appliances containing Chlorofluorocarbons (CFCs) and Volatile Organic Compounds (VOCs; not further addressed here). Material Flow Analysis (MFA) and Cumulative Energy Demand (CED) were applied to describe and analyse the different technologies. In order to analyse the environmental impact budgets for CFCs, CO_2 (Carbon Dioxide), HF (Hydrogen Fluoride), and HCl (Hydrogen Chloride) were established and evaluated for their Global Warming Potential (GWP), Ozone Depletion Potential (ODP) and Acidification Potential (AP). However, the main purpose of the study was not the comparison of technologies but to find out how an optimal recycling target can be found. This extended the relevance of the study beyond the technical question of how to recycle fridges optimally.

The first and absolutely necessary step in such a project is to determine the average composition of the waste stream, in this case: cooling appliances containing CFCs. Data were taken from several studies where cooling appliances were dismantled and analysed (Table 1). If such data are not available, they have to be generated either by dismantling a reasonable number of appliances or, even better, from manufacturer's data. However, the latter is hardly feasible today because manufacturers are not willing to disclose such information, which is a relevant yet overcomable obstacle for the establishment of a circular economic system.

The second step is to select relevant environmental impact categories to quantify the environmental benefits of recycling. In the case of CFC cooling appliances, resource conservation was expressed by accounting for all the primary energy needed to treat the cooling appliance using the Cumulative Energy Demand (CED) as an indicator. The environmental impact was investigated based on the Global Warming Potential (GWP) and the Ozone Depletion Potential (ODP) of the system. However, this step is fully dependent on the type of waste under study and there is no general rule on how to determine relevant impact categories.

Table 1 **Average composition of end-of-life cooling appliances (Laner and Rechberger 2007)**

Fractions[1]	Cooling appliances containing CFCs	
	[%]	[kg]
Plate glass	2,2	0,89
CFC–11	0,3	0,11
CFC–12	0,6	0,25
Oil	0,6	0,26
Polyurethane (PUR)	9,9	4,07
Iron	60,2	24,69
Aluminium	5,5	2,25
Copper	2,9	1,18
Plastics	15,3	6,27
Residuals	2,5	1,02
Total	100,0	41,00

The third step is the determination of the environmental benefits as a function of the recycling rate. For CFC cooling appliances, this is illustrated in Figure 1.

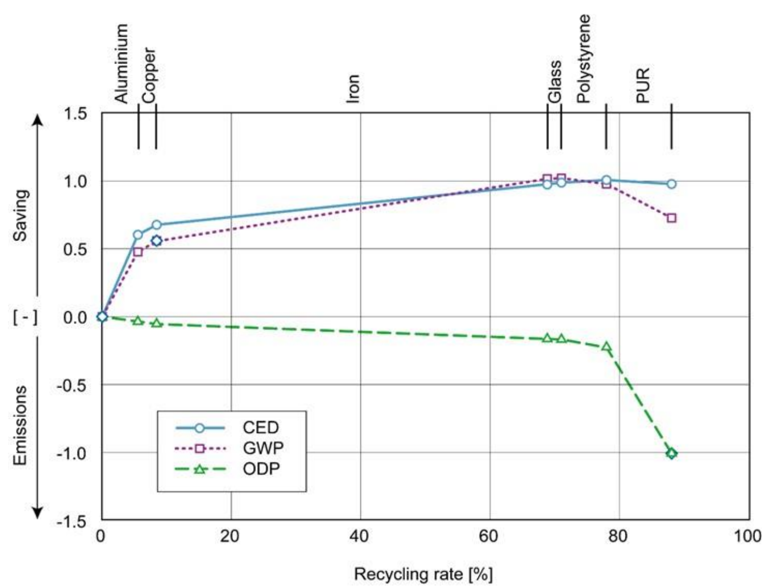

Figure 1 **Interrelation between materials recycling and investigated indicators. Each graph is normalized, with the maximum value defined as 1. For this reason the figure does not provide information about the absolute relevance of the indicators (Laner and Rechberger 2007)**

The recycling of the Aluminium parts from cooling appliances contributes most to resource conservation, expressed as primary energy savings (CED). This is because the production of secondary Aluminium requires only a fraction (around 10%) of the energy demand for primary Aluminium. Therefore, the recycling of (metallic) Aluminium is usually very beneficial. This also holds to a minor extent for Copper and Iron, as can be seen in Figure 1 (savings in CED but still only small negative effects expressed as contributions to ODP). The recycling of the other material fractions such as Glass and Plastics contribute

[1] The compressor, electric and electronic components etc. are already included in the single material fractions.

only little to nothing to the energy savings. For GWP the trend is similar to CED because in this case energy savings more or less mean the saving of fossil fuels. However, when it comes to the recycling and reuse of the PUR foam (e.g., as an adhesive agent to bind oil from spills) this reduces the savings of GWP equivalents because small amounts of CFCs escape. This negative effect is even more pronounced with respect to the ODP score. Therefore, at a certain point more recycling does not result in more gains (savings), but rather in increasingly negative effects, which is a classical trade-off situation. In the case of CFC cooling appliances and under the circumstances of Austria in 2007, this was at somewhere between 70 and 75%.

Conclusions from the case study

From this case study on CFC cooling appliances the following general conclusions can be drawn: The optimal recycling rate for a certain waste fraction or type depends on at least three factors, namely

1) the composition of the waste fraction or type (in this case cooling appliances)
2) the technologies applied, both for recycling and for producing the primary raw materials replaced by the secondary ones
3) economic aspects (if considered) because primary energy and commodity prices also play an important role for the viability of recycling

All three facts vary over time: The material composition of products changes following innovation cycles, lifestyle and fashion trends. New and better technologies are developed with respect to both aspects, that is, with respect to the primary production of raw materials as well as with regard to the production of secondary materials from recycling. And finally, commodity prices have shown increasing volatility over the past few years. All in all, this means that the determination of the optimal recycling rate for a waste type is a complex task and the result is a moving target over time. This means that the fixation of legal recycling targets is a delicate act. On the one hand, optimal and legal recycling targets should approximate one another as much as possible in order to be effective. On the other hand, the legal rate must be left of the optimum and never on the right side since this is the area of suboptimal benefits and higher expenses (see Figure 2).

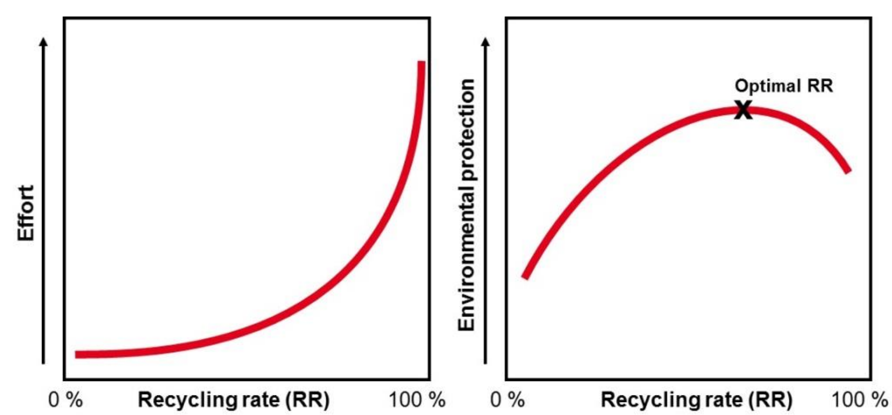

Figure 2 **The general context between recycling rate and environmental benefits. The context is dependent on waste type, technology developments and commodity prices, hence, a moving target.**

Therefore, the main lesson that can be learned from this case study is: A high recycling rate per se does not automatically result in goal-oriented waste management if resource conservation is overcompensated by resulting emissions and other adverse effects. The optimal recycling rate is a function of several influencing factors, therefore not constant over longer periods and requires careful determination based on sound data and methods.

Conclusions

Based on the results of the case study, the following conclusions can be drawn:

► The optimal recycling rate is a temporally moving target and requires careful determination.

► Determination of an ecologically and economically reasonable legal recycling rate requires the knowledge of the optimal recycling rate.

Recommendations

► Commencing studies and research to create and extend the methodological and informational knowledge to determine optimal recycling rates for relevant waste streams and secondary resources.

References

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