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Recovery rates as a tool for goal-oriented treatment of cooling appliances?

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Abstract

The treatment of cooling appliances in Austria is mainly influenced by two factors. On the one hand is the changing composition of cooling appliances because of the CFC phase out, on the other hand are the minimum recycling rates stipulated by the ordinance on Waste Electrical and Electronic Equipment (WEEE ordinance).

Two basic treatment practices can be identified in Austria: One type aiming at a maximum of material recycling and one combining thermal recovery and material recycling. The former does fulfil the mandatory recycling rates, whereas the latter does not fulfil the regulations of the WEEE ordinance. The material and energy balances of the treatment models are established both, for CFC appliances and for appliances containing VOCs. The treatment practices are compared via selected parameters: the cumulative energy demand and relevant emissions.

The results show, that a high recycling rate alone does not necessarily lead to goal oriented solutions with respect to the goals of waste management, namely resource conservation and environmental protection.

Keywords: WEEE, materials recycling, thermal recovery, cooling appliances.

1 Introduction

Two circumstances are dominating the treatment of cooling appliances in Austria. On the one hand, the CFC phase out regulated by the Montreal Protocol (1987) leads to a changing composition of cooling appliances. On the other hand, the ordinance on Waste Prevention, Collection and Treatment of Waste Electrical and Electronic Equipment (WEEE Ordinance 2005) stipulates a rate of reuse and recycling of 75 % for cooling appliances, like refrigerators and freezers.

In Austria two basic types of treatment practices can be identified. There is one kind of facility aiming at a maximum of materials recycling and another type of facility combining thermal recovery and materials recycling. The former does fulfil the regulations of the WEEE ordinance, whereas the latter does not comply with these regulations. In this paper it should be therefore examined, if these regulations lead to a goal-oriented treatment of cooling appliances with respect to the goals of waste management, namely resource conservation and environmental protection. This should be investigated for cooling appliances containing Chlorofluorocarbons (CFCs) and also for appliances containing volatile organic compounds (VOCs).

Some studies have been performed (Fehrenbach et al. 1997, S.EN.S 2000, Hornberger & Janusz 2005) which compare different treatment technologies with regard to their environmental compliance, but their findings are not based on treatment practices used in

Austria. In this paper also the suitability of recycling rates as a tool for achieving goal oriented solutions is discussed.

2 Materials and Methods

2.1 Types and composition of cooling appliances

The composition of cooling appliances is changing due to the CFC phase out. Since the mid 90s no more cooling appliances containing CFCs have been sold. For the last ten years most new cooling appliances have contained isobutene as a cooling agent and cyclo-pentane as a blowing agent. Hence, in future more and more cooling appliances containing these VOCs will have to be treated at their end-of-life (see Hug et al. 2004). Table 1 shows the average composition of these two types of cooling appliances. The material fractions were calculated using numerous sources, for more details see Laner & Rechberger (2007).

Fractions	**CFC cooling appliances**			**VOC cooling appliances**	
	[%]	[kg]		[%]	[kg]
Plate glass	2,2	0,89		1,6	0,66
CFC-12	0,3	0,11	VOC	0,8	0,31
CFC-11	0,6	0,25			
Oil	0,6	0,26		0,6	0,26
Polyurethane (PUR)	9,9	4,07		8,2	3,34
Iron	60,2	24,69		57,4	23,54
Aluminium	5,5	2,25		3,3	1,36
Copper	2,9	1,18		0,7	0,27
Plastics	15,3	6,27		26,7	10,94
Residuals	2,5	1,02		0,8	0,32
Total	**100,0**	**41,00**		**100,0**	**41,00**

Table 1: Average composition of the investigated cooling appliances

2.2 Treatment practices

The two treatment types are investigated by first establishing a basic model based on the data available about the practices used in Austria. Then variants of this basic model are developed in order to take uncertainties, data gaps and other models belonging to the same treatment type into account.

The description of the treatment practices will be given only for CFC appliances; nevertheless the practices were also investigated for VOC appliances. The main difference when treating VOC appliances, apart from the composition, is the destruction of the cooling and blowing agents, which are not cracked in a high temperature process but incinerated in a waste-to-energy plant.

2.2.1 Treatment type with a maximum of materials recycling (MM-type)

This treatment practice consists basically of two steps. At first the coolant is removed from the appliances and dismantling (removal of compressor, cables, plate glass, mercury switches and capacitors) is carried out. Afterwards, the pre-treated cooling appliances are shredded in an enclosed unit. The released blowing agent in the process gas is captured in an activated carbon filter system and then condensed. The captured CFC is cracked into HCl, HF and residues in a high temperature process. The generated material fractions are separated and widely recycled. Throughout the separation process de-gassed PUR powder is produced. This fraction is then recycled as an adhesive agent. Information about this treatment type was provided by operators of this kind of facilities in Germany, publications by RAL (2003, 2005) and other literature sources (Fehrenbach et al. 1997).

From the basic model several variants are derived: Cryocondensation, Reduced purity of the polystyrene fraction, Industrial combustion of the polystyrene, Mixed fraction "PUR powder", Direct incineration of the "PUR powder", Consideration of internal transport processes.[1]

2.2.2 Treatment type with combined thermal recovery and materials recycling (TM-type)

The first step coincides largely with the MM-type, with the difference that here an in-depth dismantling (plastic parts, electric components, iron and other metal parts are additionally removed after the de-gassing) of the cooling appliances is carried out. Then the pre-treated appliances are shredded and directly afterwards incinerated in a rotary kiln for hazardous waste treatment, equipped with advanced air pollution control. The process gas is used as a combustion air in the incineration process, where the CFCs are fully destroyed. After the incineration iron is separated from the bottom ash before it is landfilled. The information about this treatment practice stem from literature sources (Gabriel 2004, Winkler 1996) and from the operators of the only facility of this kind in Austria.

Also for this treatment type variants are derived from the basic model: Increased efficiency of the metals separation (Fe and Al) from the bottom ash, Consideration of internal transport processes.[1]

2.3 Comparison of the treatment practices

The treatment practices are compared via materials and energy balances, both for CFC appliances and for VOC appliances. The balances also include the expenditures for producing the recycling goods out of the different material fractions. The benefit allocated to a certain output fraction is determined on a utility basis, which means that the recycling good and the replaced good have to achieve the same utility. For combustible output fractions which are materially recycled, it is assumed that after their "secondary" useful life they are incinerated in a waste-to-energy plant.

The indicators for expressing the results of the comparison are selected with respect to the goals of waste management. The cumulative energy demand (CED) (see VDI 1997) represents resource conservation. Emissions of CFC, HCl, HF, CO_2 and solid residues are a measure for the environmental impact caused by the treatment practice.

3 Results

The savings in cumulative energy demand by the different treatment models are presented in Figure 1. Generally the models of the MM-type achieve higher savings of primary energy

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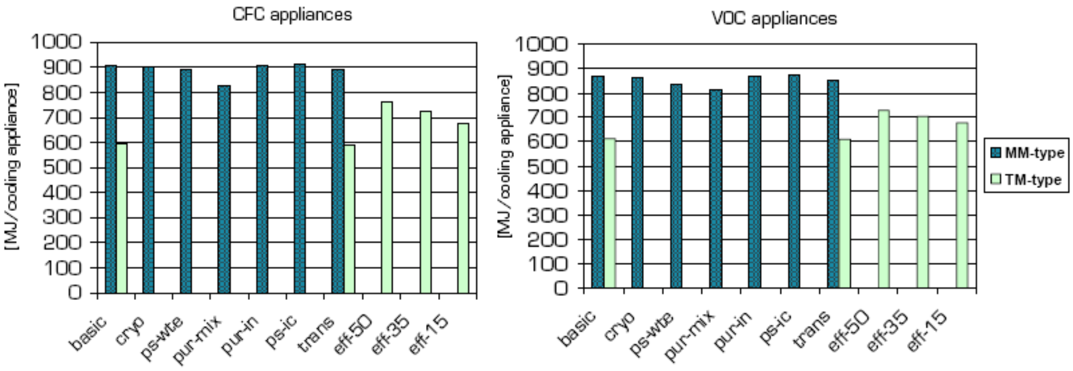
[1] For a more detailed description of the basic model and the variants see Laner & Rechberger (2007).

than those of the TM-type. It is apparent, that the variants of the TM-type with an advanced separation of metals achieve substantially higher savings of CED. This indicates that an efficient recovery of metals is very important with respect to resource conservation. Especially the recycling of aluminium, because of its high energy demand in primary production, is a crucial aspect in this context.

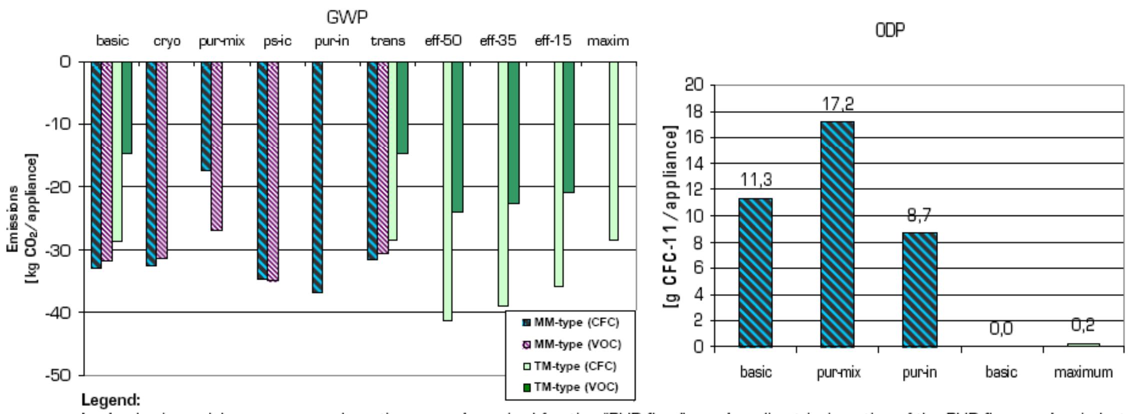


Legend:
basic - basic model, **cryo** – crycondensation, **ps-wte** – reduced purity of the polystyrene fraction, **pur-mix** – mixed fraction "PUR flour", **pur-in** – direct incineration of the PUR flour, **ps-ic** – industrial combustion of the polystyrene, **trans** - consideration of transport processes, **eff-50** – aluminium separation efficiency of 50 %, **eff-35** – aluminium separation efficiency of 35 %, **eff-15** – aluminium separation efficiency of 15 %;

Figure 1: Savings of cumulative energy demand achieved by the treatment models

The results of the balances for the selected emissions are presented in an aggregated way in this paper. The results are shown in Figure 2 for the impact categories global warming potential (GWP) and ozone depletion potential (ODP). The acidification potential (AP) and the solid residues are not shown in this paper, as they turn out to be of minor importance on a national level.

The treatment of cooling appliances according to the investigated models leads to savings of global warming potential (see Figure 2 left). For CFC appliances the release of CFCs (they are very potent greenhouse gases) leads to a similar saving achieved by both basic models. For VOC appliances the relative savings are similar to those already observed for the CED, so generally higher for the models of the MM-type.



Legend:
basic - basic model, **cryo** – crycondensation, **pur-mix** – mixed fraction "PUR flour", **pur-in** – direct incineration of the PUR flour, **ps-ic** – industrial combustion of the polystyrene, **trans** - consideration of transport processes, **eff-50** – aluminium separation efficiency of 50 %, **eff-35** – aluminium separation efficiency of 35 %, **eff-15** – aluminium separation efficiency of 15 %, **maximum** – scenario with a maximum of CFC emissions;

Figure 2: Results of emission balances expressed by selected impact categories

In Figure 2 (right) it can be observed that the treatment models of the MM-type are associated with a release of ozone depleting substances. The CFC emissions for all the investigated scenarios are in a range between 4 and 17 grams per CFC appliance. The basic scenario amounts for 11,3 grams of CFC emissions. The main paths for the CFCs into the atmosphere are the release of residual CFCs from the de-gassed PUR powder throughout its use as an adhesive agent and the PUR foam adhered to other fractions. When treating CFC appliances according to the MM-type these emissions have to be minimised, as they are also relevant on a national level (Laner & Rechberger 2007).

4 Discussion and conclusion

The previous findings show that a maximum of materials recycling does not necessarily lead to goal oriented solutions in terms of waste management. The metals contained in the cooling appliance are very important with regard to resource conservation, whereas the recovery of other materials has a minor influence on the achieved savings of CED. For example the material recycling of the PUR insulation of a CFC cooling appliance as an adhesive agent, does not contribute to resource conservation (it replaces mainly other waste products instead of primary resources), but it is associated with a substantial release of CFCs into the atmosphere. Therefore the optimal recycling or recovery option of a material is based on the substituted goods and the related emissions. So it can be stated that recycling rates should be specified on the level of materials, but not as overall recycling rates for whole appliances.

In Figure 3 the interrelations between different recovery options, the achieved resource conservation and associated emissions are shown. For those materials which can be either materially or thermally recovered (mainly plastics), it can be observed that material recycling is not a priori more beneficial than thermal recovery with respect to resource conservation, but may be connected with a completely different level of emissions.

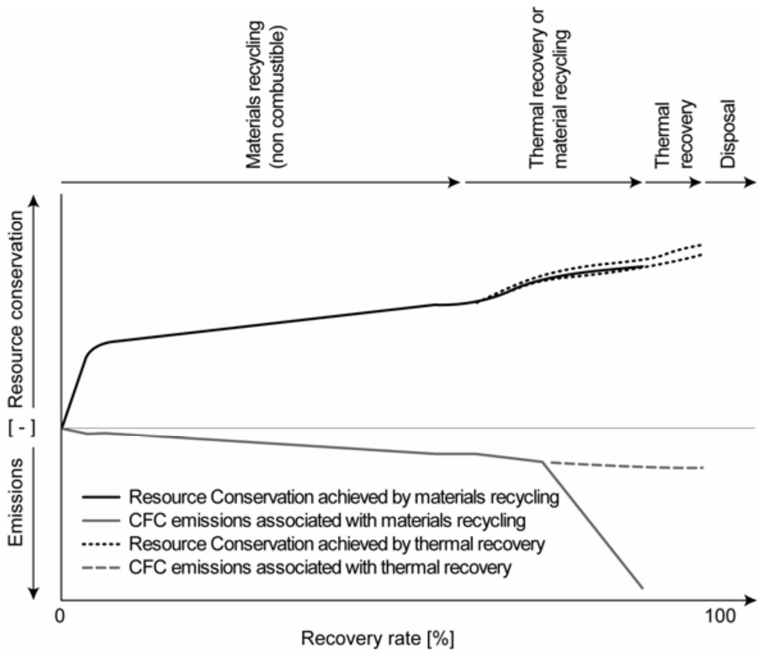


Figure 3: Dependencies between different recycling and recovery options with respect to resource conservation and CFC emissions (Source: Laner & Rechberger 2007)

Hence, the optimal recycling rate is a function of the material composition of a device and the technologies applied in primary production as well as in recycling. A high recycling rate on its own does not automatically lead to goal oriented solutions.

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