Collective, Collaborative or Competitive?

An Analysis of EPR Approaches using Material Recovery Certificates for the Recycling of Cooling and Freezing Appliances in Austria

Philipp Bohr, Timothy Gutowski

Massachusetts Institute of Technology,

Laboratory for Manufacturing and Productivity,

77, Massachusetts Avenue, 02139 Cambridge, MA, USA

bohr@mit.edu, gutowski@mit.edu

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1. The European EPR system landscape for WEEE recycling

The evolution of Extended Producer Responsibility (EPR) for WEEE recycling in Europe has proven to be widely varied in terms of system design and the enforcement of concrete requirements set by the EU WEEE directive. The regulatory framework for an efficient and ecologically effective producer responsibility system is, however, still contentious. The original intention of the WEEE directive was to create an individual producer responsibility for electronic waste, connected with the idea that the responsibility for individual waste management would help to further green design. Individual responsibility has, however, not been embedded in European system practice. Taking practically no notice of article 4 (product design) of the WEEE directive, national authorities have granted the right to producers to collectively assume responsibility. Currently, collaborative and competitive approaches can be distinguished in an attempt to categorize systems. In collaborative approaches, e.g. to be found in Belgium, Sweden, Norway, Denmark, and the Netherlands, a single producer responsibility organization (PRO) rules the market and organizes take-back and recycling almost as a monopolist. In competitive approaches, as found in Germany, Austria, and soon Italy, several service providers work the take-back market. Their market share is usually controlled by a national clearing house that monitors their take-back and recycling performance. Both approaches have their advantages and drawbacks. Monopolistic PRO approaches can leverage economies of scale in several areas, for example administration, quality control, or transport. Further, the take-back and recycling system can work with established local teams and interface issues with other organizations can be avoided.

However, monopolistic approaches can be criticized since they might not strive for cost-efficiency due to their market power.
Current competitive approaches lack economies of scale due to the existence of several service providers acting on behalf of producers. The respective take-back market is either organized as an open market with direct contracts under a framework with several requirements, as in Austria, or with a central pick-up order allocation mechanism, as in Germany. The latter approach bears substantial difficulties due to a lack of decentralized decision-making and enormous logistics and organizational burdens created by the centralized allocation.

First market observations seem to indicate that competitive solutions yield lower costs (Hieronymi 2007). However, cost-efficiency in achieving "compliance" is not a good indicator for the superiority of a system if quality standards and their enforcement are not clearly defined. As the recycling practice in Europe indicates, substantial disparities arise among EU countries with respect to the adherence to depollution standards set in Annex II or the achievement of recycling rates. Since recyclers face economic disincentives for thorough depollution because of time savings in manual separation and cost savings for the disposal of hazardous items, it is extremely important to enforce quality standards and thoroughly monitor the adherence to them. Alternatively, a (competitive) system can be designed in a way that the overall economic incentive structures faced by recyclers are structured in a way that it is in the best interest for the recycler to achieve depollution and recovery standards. Material recovery certificates (MRCs) can help achieving these incentive structures. MRCs reflect the recycler's performance and connect it where necessary with financial incentives. This will be illustrated with an analysis of cooling and freezing appliances recycling. First, the typical recycling process for this WEEE group will be portrayed, followed by a description of existing incentive structures. Afterwards, the MRC approach will be described and simulation results will be used to contrast it with current system practice.

2. Recycling of Cooling and Freezing Appliances

The state-of-the-art in recycling of waste from electrical and electronic equipment requires its separation into at least five groups due to different preconditions and technologies applied for each group. The five groups are

(1) cooling and freezing appliances,

(2) televisions, monitors, and other cathode ray tubes,

(3) large (household) appliances,

(4) small (household) appliances,

(5) lighting equipment (gas discharge lamps).

Cooling and freezing appliances require specialized recycling equipment because the appliances contain CFCs with enormous global warming potential and fluids that have to be removed. Both insulation material and cooling circuit can contain environmentally harmful gases that have to be recaptured and destroyed according to the WEEE directive (COM 2003). The standard treatment procedure for cooling and freezing appliances is as follows:

First, remaining food wastes and glass/plastic shelves are taken out. The power cable is cut off and the appliances are checked for hazardous items such as mercury switches and polychlorinated biphenols containing capacitors that are manually removed. Second, the appliance is brought to a sucking station (step 1), usually on a roller conveyor. The recovery of CFCs is done in two steps, step 1 dealing with the liquids in the cooling circuit and step 2 recovering CFCs from the insulation. In step 1, the cooling circuit is spot-drilled with a special pincer and the refrigerant and oil are completely sucked off. In Europe, a distinction between three appliance classes is made for the requirements in step 1. The most important group are appliances that contain CFC, HFC, or HCFCs in the cooling circuit (mostly R12, R22, R134a, R404a, R502). The current share of returning appliances of that type is about 84% (representative for Germany, Austria and Switzerland in 2006, Hug 2006) and will decrease in the future due to the phase-out of CFCs. As an average value, the sucking station should recover 115g of these substances per appliance (90% of expected maximum). In addition, oil is seperately recovered from the cooling circuit with an average weight of 240g. In the second group are the HC appliances (R290, R600a) which currently have a share of 12% of the returning volumes. HC is less problematic from an environmental point of view; nevertheless, those liquids are removed as well and an average weight of 60g refrigerant and 240g oil can be expected. The third group (4% share of returning volumes) represents the ammonia appliances (NH3) which are easily identified by the thickness of the pipes of the cooling circuit. These liquids are sucked off and stored in an extra tank. The recovered amounts of cooling refrigerants can be measured and monitored with a normal pair of scales.

Step 1				
Classification	**Types**	**Global warming potential [GWP]**	**Share of returning volumes [%]**	**Expected mass to be recovered per unit [g]**
Group 1 (CFC, HCFC, HFC)	R12	10600	84	115
	R22	1700		
	R134a	1300		
	R404a	3750		
	R502	5590		
Group 2 (HC)	R290	3	12	60
	R600a	3		
Group 3 (NH3)	R717	0	4	-

Table 1: Recovery of CFCs and other gases in step 1 (IPCC 2001, Hug 2006, Field research)

After removal of the liquids in the cooling circuit, the compressors are cut off with a hydraulic cutter. The appliances (now called “cabinets”) are then further processed and reduced to small pieces (step 2). Various technologies are applied in step 2 for both size reduction and recovery of CFCs and cyclopentane from the insulation where such gases were used as a blowing agent. Most solutions use an enclosed shredder combined with nitrogen neutralization (inertisation, due to explosion potential of VOCs/HCs) for size reduction and a cryocondensation unit in order to recover the CFCs and cyclopentane from the gas stream that is sucked off from the shredder chamber. Additional equipment is necessary to decrease the residual CFC content in the shredded polyurethane pieces to the mandated standards (<0.2% residual CFC content).

Again, a distinction into three classes is apposite for step 2. The biggest share of appliances processed (about 81%) has insulation that contain CFCs (R11 and a minimal, negligible part of R12). The second largest group features insulation blown with cyclopentane (about 18%). These appliances are often processed as cabinets in a car shredder. A small remaining share of (mostly very old) appliances are insulated with glass wool or other “non-polyurethane” (1%) and needs separate manual preparation. As an average value, the insulation foam of the appliances from the first group should enable a recycler to recover 283g R11 per unit (90% value) and about 140g of cyclopentane per unit. Since some appliances were already damaged before processing or lost CFCs from the insulation for various reasons, the 283g are usually not attained in daily business. The recovery from step 2 can be monitored with raw gas measuring instruments on the input and output side and, in the case where cryocondensation is applied, with the weight of the tanks where the gases are collected.

Step 2				
Classification	**Types**	**Global warming potential [GWP]**	**Share of returning volumes [%]**	**Expected mass to be recovered per unit [g]**
Group 1 (Polyurethane insulation with R11 + minimal share R12)	R11	4600	81	283
	R12	10600		
Group 2 (Polyurethane insulation with cyclopentane)	C5H10	11	18	140
Group 3 (glass wool and other non-PUR)	-	0	1	-

Table 2: Recovery of CFCs and other gases in step 2 (IPCC 2001, Hug 2006, Field research)

After shredding, the material from the appliances is sorted into ferrous metals, non-ferrous metals, a polystyrene-dominated plastics fraction and a polyurethane fraction. Standard sorting equipment (eddy current, magnetic separator) is sufficient for these purposes. Ferrous metals are usually directly obtainable in a high separation quality (>99%) and are sold to steel mills. The non-ferrous fraction usually goes to secondary recyclers for further separation of metals or directly to foundries that can use the material mix in the manufacturing of aluminum parts. The plastics fraction is further processed by plastics recyclers that focus on the polystyrene in order to reapply it in new plastic components. The polyurethane is usually reapplied as oil binder, used for methanol synthesis, or burned for energy recovery. Cables go to a cable recycler in order to recover the contained copper. The compressors are in principle reusable or can be further processed by secondary recyclers in order to recover the materials (ferrous metals, copper).

3. Material Recovery Certificates (MRCs)

The characteristics of several market designs for the use of (tradable) material recovery certificates are analyzed and discussed in detail in (Bohr 2007). In general, MRCs are to be issued by recyclers based on the amount and quality of fractions produced. They serve as the refinancing mechanism for recyclers and MRCs are sold to producers who are obliged to buy MRCs in order to fulfill their EPR obligations. For the purposes of this paper, a quick overview of the supporting rationale with regard to the aforementioned incentive structures is given.

A key difference between current collective approaches and approaches with MRCs is the anchorage point of payment mechanisms. Currently, recyclers are paid according to input processed. MRCs and payments under the MRC approach are based on output produced. This is driven by the idea that the actual recycling service is characterized by the processing level/ treatment depth of a recycler (how much of the incoming material is fed back into the loop and which level of reapplication) and by the depollution performance (how many hazardous wastes are diverted from their reentry into ecosystems).

Currently, recyclers easily attain both quotas mandated for this waste category by the WEEE directive because economic incentives for recyclers are aligned with the achievement of a recycling and recovery quota of 75% or 80% respectively. Current prices for secondary metal fractions ensure that a recycler attempts to recover all metals as pure and comprehensively as possible. The same holds for the polystyrene-dominated plastic fraction that can achieve prices in the same range or even higher than the ferrous metal fraction. Summing up these fractions already yields a recycling rate of 86.56% (if the fractions are fully acknowledged as material recycling). A totally different situation applies for the recovery of CFCs. The efforts of an environmentally conscious recycler to recover as much CFC as possible are penalized with downstream CFC destruction/cracking prices of up to 5500 €/t. In addition, it is necessary to keep recycling equipment always in good condition (with respective maintenance cost) in order to achieve high CFC recovery results. Accordingly, recyclers face strong economic disincentives to meet high CFC recovery standards in their daily business. Observing recycling practice in Europe reveals that these economic disincentives influence the recycler’s behavior, e.g. when it comes to handling of old appliances at the recycler’s site or during transport (outside storage, damage to the cooling circuit due to unskillful handling). As a result of this behavior, considerable amounts of CFC can be released to the atmosphere that would otherwise be recaptured if appropriately incentivized. Surprisingly, no mandatory recovery quota applies for the recovery of CFCs under the WEEE directive. This is even more astonishing as the CFCs are deemed the major environmental concern in the recycling of cooling and freezing appliances. Nevertheless, CFC recovery in the daily operations is usually not monitored by system operators. Although specialized plants do only exist because of the CFC recovery problem, payments and monitoring efforts do not usually account for CFC recovery performance. Given these considerations, the monitoring and enforcement of recycling quotas seems rather obsolete in the case of cooling and freezing appliances. Instead, the regulatory framework should focus on incentives for high CFC recovery and destruction and incentives for a high level of reapplication of problematic fractions such as the PUR fraction. Table 3 shows a representative split of recoverable materials from cooling and freezing equipment in Europe. The shares are calculated according to the return stream characteristics defined in table 1 and 2. MRC relevant fractions are identified and the recommended MRC coefficients for each fraction are on the right side. CFC recovery performance in daily practice is assumed slightly below 90%.

Code	**Fraction description**	**Share [f_i]**	**MRC Coefficients [c_i]**
19 12 02/ 01-2	Ferrous metals (>99% pure)	47.000%	0
19 12 03/03-1	Aluminum/Copper	5.400%	0
16 02 16/ 12	Compressor	21.319%	0
16 02 16/ 10	Cables and wires	0.380%	0
19 02 07*/01	Oil	0.480%	0
19 12 04/ 02-1	Plastics (approx. 80 % polystyrene)	12.459%	5
19 12 04/ 05-1b	PUR foam (insulation)	9.760%	5
20 03 01	Non recyclable items (e.g. food residues)	1.560%	0
19 12 12	Glass wool and "non-PUR"	0.170%	0
14 06 03*/ 02	Cyclopentane (step 2)	0.050%	0
14 06 03*/ 02	R290, R600a (step 1)	0.010%	0
14 06 03*/ 01	NH3 (step 1)	-	0
19 12 05	Glass (from shelves)	0.700%	0
19 12 11*	Condensation water	0.330%	0
16 02 15*/01-2	Mercury components	0.001%	100
16 09 02*/ 02	PCB suspect capacitors	0.000%	100
14 06 01*	R11+R12 (step 2)	0.505%	500
14 06 01*	R12, R22, R134a, R502 (step 1)	0.205%	500
	Total	100.330%	

Table 3: Material split in the recycling of cooling and freezing appliances (Hug 2006, Field research)

It is important to bear in mind that the coefficients do not represent an attempt to assign ecologically adjusted weighting factors to fractions. It solely serves to amend and complement existing (financial) incentive structures in order to achieve sound recycling practices.

Accordingly, current pricing of fractions has been taken into account when choosing the coefficients. MRCs are issued according to: $MRC[t] = \sum_i f_i \cdot c_i$ (1)

For cooling and freezing appliances, the expected amount of MRCs per ton input with the setup defined in table 3 is $MRC[t] = 4.6557$

4. Policy Model and Simulation Results

In principle, MRCs can be used in collaborative as well as competitive system setups. In order to analyze the outcome of different policies, a comprehensive simulation model has been devised that is presented in (Bohr 2007). For this paper, it was assumed that MRCs are used in a collaborative setup and that collection and logistics are covered separately. The key parameters for the treatment simulation are

- the country- and time-specific waste potential coefficient $w_{i,t}$ in conjunction with the population size P
- average capacity utilization $cu_{i,t}$
- average capacity $ac_{i,t}$
- labor cost l
- energy price ep
- weighted average cost of capital including yield expectations $wacc$

According to our model, Austria faces about 370.000 units in 2008 with an average expected weight of 42 kg. The key parameters used for the market simulation are shown in table 4:

$w_{i,t}$	1.8874 kg/capita
P	8'233'306
$cu_{i,t}$	56.05%
$ac_{i,t}$	12800 t/year
l	15.47 €/h
ep	0.0896 €/KWh
$wacc$	15%

Table 4: Key simulation parameters

Figure 1 shows the interdependence of the certificate price and the average capacity utilization, given the parameters from table 4 and assuming that the 90% CFC recovery targets are met in daily practice.

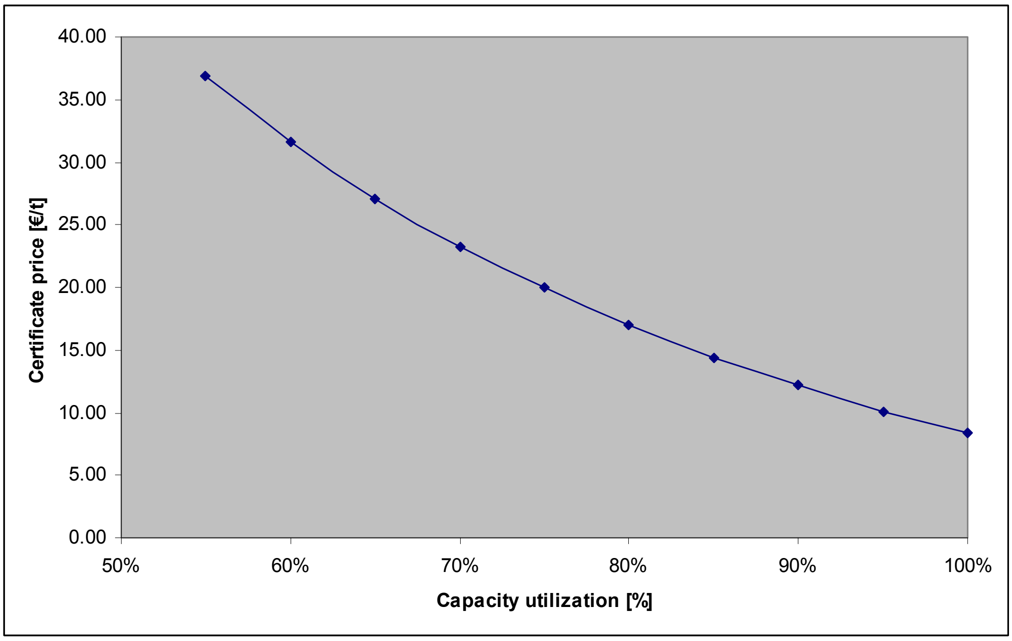

Figure 1: Certificate price over capacity utilization

Figure 2 shows the impact of the quality level (defined as percentage of CFC recovery) on the recycler profit under the MRC setup, given a fixed certificate price of 40 €/t and the parameters from table 4. It is assumed that two big plants with a model capacity of 303.500 units are absorbing the volumes, resulting in an average capacity utilization of 56.05%.

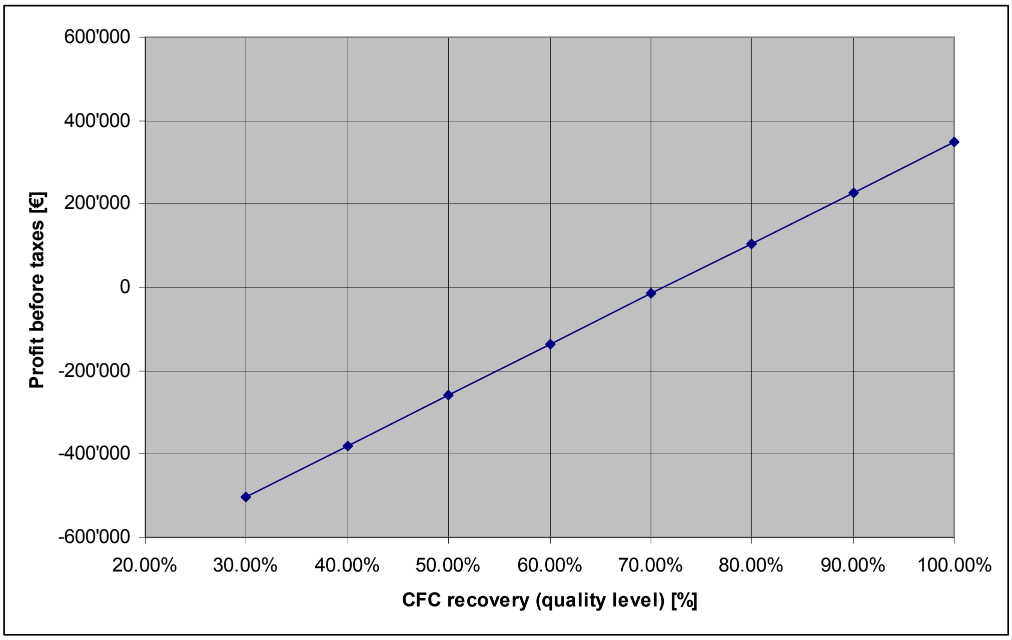

Figure 2: Profit over quality level

5. Conclusion

Current input-based remuneration mechanisms for WEEE recycling in Europe do not set incentives for environmentally sound recycling practices. Since high quality recycling does not pay off for recyclers under such remuneration mechanisms, recycling quality is likely to decrease under the cost-pressure of producers. Regulatory authorities should address this issue and set rules for EPR in a way that incentive structures in practice foster high quality recycling. Using an MRC approach can serve to set such incentive structures. As figure 2 indicates, the quality level has a major impact on the profit of a recycler under the MRC market setup. The quality level can be monitored and data could be directly transferred to an independent regulatory authority (e.g. as it already happens with environmentally critical parameters from waste incineration plants in Europe). The independent authority can control the issuance of certificates and producers can fulfill their EPR obligation via the purchase of certificates.

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