Policy Tools for Electronics Recycling

Characteristics of a specific certificate market design

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***Abstract* - Several countries across the globe have implemented or are about to implement specific electronics recycling regulations based on the principle of Extended Producer Responsibility (EPR). Both existing and proposed solutions are implemented with various degrees of centralization; one solution involves a steering regulatory authority, another connects the EPR with strong competitive market structures. As different WEEE recycling approaches evolve, the best way to achieve a cost- and eco-efficient system organization is still contentious. Theoretical system characteristics intended by policy-makers and their realization in practice often don't coincide. Practical implementations can give rise to absurd organizational outcomes. Some incentive structures are counterproductive, and actual environmental purposes of recycling legislation are often poorly reflected. This paper presents a specific certificate market tool that potentially has intriguing properties in terms of system performance, control, organization and cost. The approach introduces competition on several levels in the value chain and sets incentives for the eco-efficient treatment of WEEE. In addition, it enables decentralized decision-making which is one of the key levers for a cost-efficient system organization in a competitive market setting.**

Keywords – policy tools, certificate market, WEEE regulation approaches

I. INTRODUCTION

Extended Producer Responsibility (EPR) is a relatively new and market-oriented regulatory instrument. The Organization for Economic Cooperation and Development defines it as "an environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle" [22]. An application of EPR for electrical and electronic equipment is certainly appropriate. Large amounts of waste from electrical and electronic equipment (WEEE), e.g. approximately 10 million tons per year in the European Union [20], have put enormous pressure on all institutions involved in the end-of-life management of electronic devices. WEEE is among the fastest growing categories of municipal solid waste and constitutes approximately 4% of the overall municipal solid waste stream [4,12].

These facts have recently led to vigorous action among legislative bodies across the globe. Several countries have already implemented specific electronics recycling regulations, e.g. Norway, Sweden, Holland, Switzerland, Belgium, and Japan [16,25,29]. Directives in other industrialized countries or regions, e.g. Europe (WEEE directive) or the United States, are still pending or about to be implemented [17].

All these regulatory approaches rely on the principle of Extended Producer Responsibility (EPR), and a command & control approach is chosen for its enforcement. However, the actual policy design chosen by regulatory authorities has to be carefully analyzed in terms of its feasibility in practice. Policy makers should account for the considerable cost impacts of different organizational system designs. These are only revealed by a detailed analysis of the actual actions and activities in electronics recycling practice. Such concerns were neglected in the case of the WEEE directive in the European Union where a consistent mapping of theoretical goals and practical implementation will not likely be achieved. Consequently, the potential of alternative or additional policy tools should be analyzed and evaluated.

II. DRAWBACKS OF EXISTING SYSTEMS

A. Command & Control approaches under the WEEE directive

At first, each member state's freedom to interpret conceptual rules set under a policy framework like the WEEE directive might look appealing. The difficulty in finding a detailed, politically achievable EU compromise corroborates this notion. Experience with different implementation approaches also creates the opportunity to learn from best practice in different countries. However, this also comes with a few disadvantages. The vague definition of system design rules under the WEEE directive can not only endanger a level playing field in the European Union [28] but also creates considerable uncertainty among original equipment manufacturers (OEMs) which are facing new take-back responsibilities. As a result, a relative boost of the manpower to ensure legislation conformity in OEM companies creates substantial cost burdens.

Furthermore, some additional drawbacks are existent. Most national implementation approaches chosen under the WEEE directive

- fail to create a design feedback loop to the manufacturer.

- do not account for eco-efficiency in recycling.
- set disincentives for OEMs to foster the collection of WEEE via consumer information – although hardly articulated by any of the stakeholders.
- lead to cross-subsidizing between product categories dependant on consumers' behavior.
- entail inefficient organizational structures that are far from being simple and clear.
- do not allow for decentralized decision-making.

The first two aspects are widely known and described in literature [18,28]. The disincentives for OEMs with respect to consumer information result from the measurement of their recycling duties which are mostly based on their *relative* share of returned WEEE. The less WEEE that is collected or introduced in the (national) recycling system, the less is their resulting monetary obligation. Such an incentive structure is especially worth noting against the background of occurring WEEE exports in industrialized countries, where electronic scrap ends up in third world countries. This allocation and measurement approach also entails a cross-subsidizing between product categories dependant on consumer behavior. Some devices are more likely not to be found in separate collection boxes but in export streams to less developed countries or in municipal solid waste boxes [19,30]. The result is a considerable distortion of monetary obligations for OEMs. However, assuming an industrial ecology perspective, an alignment of recycling duties with the virgin or new material consumption of OEMs would be more appropriate.

The last two aspects, namely inefficient organizational structures and the lack of freedom for decentralized decision-making can shortly be illustrated with the planning status of the German system. Here, a central public authority ("Stiftung Elektro-Altgeräte Register") acts as a clearing house, collects sales data from OEMs, and calculates their market share in each category. A direct assignment of these shares to collected WEEE amounts is impossible because 5 boxes are used for collection in practice, whereas the WEEE directive defines 10 product categories. This mismatch gives rise to the collection of different product categories in the same box. German authorities plan to continuously analyze statistical samples with respect to the waste composition of collection boxes. The system organization requires such analyses in order to be able to calculate appropriate market shares for the determination of recycling obligations. This entails continuous expenditures to ensure that the calculation basis is valid over time [31].

Costs caused by these monitoring efforts are, however, dwarfed by the system costs arising due to (under the policy necessary) inefficient allocation mechanisms of take-back obligations. The assignment of take-back orders for WEEE containers filled at municipal collection sites is planned to be made according to a random-based allocation mechanism. This is deemed necessary in order to avoid "cherry-picking". Such a system obstinately ignores the benefits of regional partnerships. Instead of relying on cooperation with a restricted number of recycling and logistic partners, OEMs have to organize take-back all over the country. This gives rise to considerable additional efforts for communication, price negotiation and coordination of logistics, and destroys economies of scope and scale.

B. Centralized systems with coordinating authorities

Most small countries use a mechanism where a centralized authority coordinates take-back, logistics, and recycling. Recyclers are contracted by regulatory authorities and orders are centrally assigned which allows for regional partnerships and well-established teams to perform the necessary tasks. OEMs are not involved in planning tasks and are only indirectly financially responsible for the WEEE transport and treatment. This results in considerable savings in both organizational efforts and management costs for OEMs. An implementation example is Norway where three industry entities (ElRetur, Renas, and Batteriretur) share the organization of take-back for all sorts of electronic devices. [1,10,24,25,27]

From an organizational point of view, these systems are superior to the more competition-oriented German system where a reasonable allocation mechanism of take-back orders hasn't been achieved. However, competition lowers the recyclers' acceptance fees for electronic waste. For example, German recyclers currently accept prices around 220 €/ton (including logistics) for the treatment of TVs and monitors; the respective prices in the adjacent Swiss system are about twice as high[1] [23].

A comparison of current WEEE recycling regulation approaches seems to reveal a trade-off between organizational inefficiencies and cost inefficiencies due to a lack of competition. However, a different system design might be able to set advantageous incentives and combine the favorable characteristics of both approaches.

III. ALTERNATIVE POLICY APPROACHES

A. Prior work and state-of-the-art in research

Free market tools provide promising alternatives for a regulation of electronics recycling. Several scientists have been advocating for a broader use of such tools to tackle environmental issues, and a strong emphasis is placed on the necessity to internalize externalities in a cost-efficient way [6]. Especially certificate markets have been subject to vigorous academic interest, but their suitability for electronics recycling has not been demonstrated yet.

Transferable permits have been analyzed as policy instruments from the 1960s on. Based on early works [5,7,8,9], it has been formally proven [21] that no alternative regulatory scheme can achieve a given environmental standard at a lower cost than a permit-trading scheme. Since then, tradable permits have been used in the case of SO2 emissions, water emissions, municipal solid waste recycling credits, fishery quotas and land development rights [3].

[1] Swiss recyclers face more strict legal requirements with respect to polymer utilization; however, this does only justify a small part of the price difference.

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To date, there is little experience in the application of certificate markets in the area of solid waste recycling. Indeed, up to now, the only practical implementation analyzed in the literature is the application of tradable permits for packaging waste recycling in the UK [26]. Spatial and temporal flexibility as well as decentralized decision-making have been identified as key drivers leveraged to boost cost-efficiency. Drawing on this experience, a generic report has been prepared for the EU commission analyzing the possibility of using a similar system for WEEE recovery [11]. Such certificate markets must, however, be carefully designed for the specific characteristics of the system. Awareness of the manifold design options of these instruments is still not widespread among decision-makers and stakeholders [26]. Accordingly, the tendency to reject policy initiatives based on a stereotypical notion of certificate markets compromises the implementation of such policy tools in practice [13]. Because electronics recycling is characterized by several different features, the direct transfer of the policy design chosen for the PRN system into a policy tool to shape the electronics recycling system is inappropriate.

B. An output-based variant of a certificate market design

Several design variants have to be evaluated in order to find a solution with satisfying properties. The lack of clearly defined goals to be pursued with electronics recycling impedes the search for an optimal design. Based on a generic industrial ecology assessment framework and a respective clarification of goals [2], a specific output-based certificate market design has been developed. Working with such a design requires

- *defined anchorage points to measure "recovered material" in the system.*
- *standards to define the quality of secondary materials.*
- *an environmental scoring or weighting system for the recovered materials (a simpler system without different material weights is possible as well).*

Expertise for suitable classification of secondary material fractions (which is the main precondition for the first two aspects) has been developed in systems with centralized regulatory authorities. For example, ElRetur in Norway has set up a unique accounting model for all outgoing materials from their treatment partners, based on 44 fractions [33]. Furthermore, the WEEE Forum, an association of collective take-back systems in Europe, works on the classification of final fractions in order to achieve a suitable reporting system for treatment results in WEEE recycling [34]. Other (quality-defined) secondary material fraction models are already used in DfE software tools [15].

Defining environmental scoring factors is a more challenging task. Approaches might be based on environmental assessment methodologies like the eco-indicator 99 [14] or other tools. While industrial ecology research might allow for further insights in the future, an initial market design is also possible without differentiated scoring factors.

Given these parameters, the certificate market works with most of the EPR principles. However, it creates significantly different monetary flows in the system when compared to the approaches portrayed in section II. Fig.1 shows a system typically occurring under the WEEE directive, while Fig.2 illustrates the flow structure for the certificate market design.

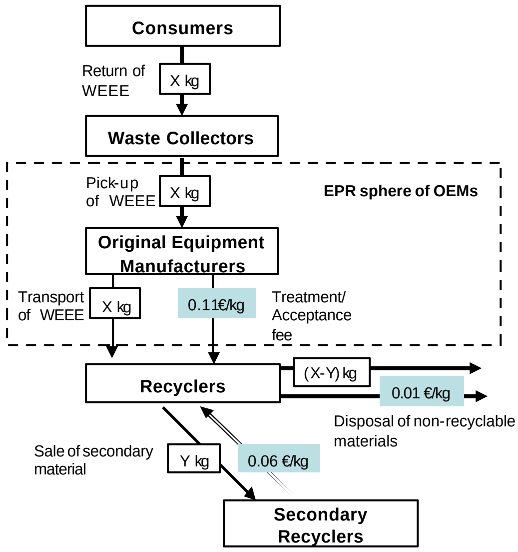

Figure 1: Simplified material and monetary flows under the WEEE directive.

Under most "WEEE directive" systems, take-back is free for consumers and collection is mainly achieved by municipalities and retailers. OEMs are responsible for pick-up of WEEE at collection points and for financing transport to recyclers. One main revenue source for the recycler is acceptance fees for the treatment of WEEE, paid by the OEMs. Recyclers derive further revenues from resale of recycled material and pay for final waste disposal of materials that can't be recycled. This also includes the disposal of hazardous materials.

Under an output-based certificate market, the recycler's scope and responsibility on the value chain is enlarged and incentive structures are fundamentally altered. The system performance is directly controlled by regulatory authorities and measured in material recovery certificates (MRCs).

Take-back is also free of charge for consumers in the output-based certificate market. Incentives for consumers to return products might occur, although barely on a large scale. Only the return of specific appliances might be specially advertised or induced by other means. Collection is paid for by recyclers and is performed by municipalities and other waste collectors. Recyclers purchase WEEE from municipalities and other waste collectors instead of obtaining an acceptance fee. Resale of recycled material and payments for final disposal of materials are similar to the outcome under most "WEEE directive" systems. One main revenue source for recyclers is the generation of material recovery certificates (MRCs) that are purchased by OEMs in order to demonstrate the fulfillment of their EPR obligation.

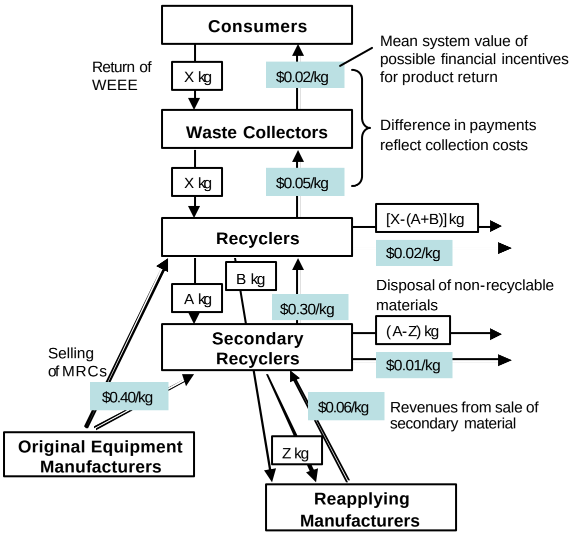

Figure 2: Simplified material and monetary flows under the certificate market.

The material recovery certificates (MRCs) are issued by recyclers on the basis of quality-defined output fractions generated by their processes. A weighting according to their environmental impact and ecological significance is possible via scoring factors, as in

$$\sum_{fractions} mass_i \cdot scoring\ factor_i = \#\,MRCs\,[kg/month] \quad (1)$$

The determination of the OEMs' recycling duties is determined via their material use for new products put on the market. This results in an *absolute* amount of MRCs to be purchased by OEMs. A simple solution looks like

$$\sum_{devices} a_i \cdot w_i \cdot p = \#\,MRCs\,[kg/month] \quad (2), \text{ with}$$

a_i = amount of devices i put on market [pieces/month]

w_i = average weight of device i [kg/piece]

p = system recycling performance parameter

However, a more sophisticated method to determine recycling duties is possible in order to set incentives for the achievement of a cycle economy in the electronics industry. One favorable feature is to systematically reward OEMs that make use of recycled material in new products. Another is to foster component reuse via MRC discounts. A promising approach to *close the design feedback loop* is the application of a virtual feedback system. This is possible via already available software tools that are able to indicate a reference recycling strategy for a product [15]. OEMs could be accordingly rewarded for their green design efforts.

C. *Characteristics of the certificate market design*

Large-scale recovery of high-quality secondary materials draws on the individual capabilities and expertise of recyclers. A sorting of WEEE according to 10 different producer or product classes like it is defined in the WEEE directive is not target-oriented. Collection and sorting in boxes should be tailored to recycler's needs. This will only happen if the recyclers have power to influence the way WEEE is collected. In the output-based certificate market system, recyclers buy WEEE for processing from waste collectors. Collectors should be certified and might be obliged to prove that WEEE stems from collection points in the system in order to avoid boundary issues. The better the WEEE suits the recycler's operations, the more the recycler is willing to pay, so better recyclable products might achieve a higher price in collection. Working with return incentives for products is possible for collectors. Higher take-back rates of certain products pays off because recyclers can realize economies of scale and avoid diseconomies of scope. This entails the following characteristics:

- Collection costs are internalized in the system and collectors are reimbursed for their efforts.
- Competition is introduced for the collection of WEEE which is likely to bring system collection costs down.
- Decentralized decision-making is possible and recyclers can leverage their individual capabilities.
- Appropriate sorting can yield productivity gains in a magnitude of 20-30% [23,32]
- Regionally different recycling infrastructure is appropriately used.
- Communication and organization efforts are minimized because the detour around manufacturers for the planning and coordination of WEEE take-back is avoided.
- Planning and structuring of logistics is facilitated through direct recycler-collector communication.
- Products with better recyclability can be targeted.

Recyclers arrange for the treatment of WEEE. The system can set incentives for each recycler to apply an eco-efficient recycling strategy according to its capabilities. Recyclers attempt to retrieve as much material in a defined quality from the WEEE as possible. This is ensured because recyclers mainly finance their activities through selling material recovery certificates (MRCs) to OEMs. The more material is recovered, the more certificates can be issued.

Minimal performance factors can be mandated to avoid "wasteful" mass recycling. To ensure this, simple aggregated figures derived from mass input/output monitoring on a facility level are sufficient. Material certificates are issued on the level of quality-defined secondary raw materials. The value of one kg of a particular recycled material depends on a scoring factor for each material. The economics of recycling operations can be influenced by regulatory authorities through the scoring factors of the (environmental) weighting method.

These system settings lead to

- competition among recyclers, which is likely to bring the price to recover a material equivalent down.
- the avoidance of definition issues, double ensemble issues and measurement issues connected to individual product performances.
- continuous rewarding of increases in recycling rates instead of inflexible mandatory recycling rates in the WEEE directive.
- eco-efficiency from a system perspective.

The OEM's obligation to recycle certain amounts of products or materials is aligned with their actual material consumption through new products sold on the market. This avoids the arbitrary dependence on consumer behavior and ensures an equitable distribution of obligations among the OEMs. The WEEE system approach already separates the calculation of obligations from actual occurred waste. Therefore, the sales data of OEMs can be used to calculate recycling obligations based on a certain percentage of the weight of products brought on the market. This percentage is the main lever for regulatory authorities to control system performance. The recycling obligations for OEMs are fixed and transfer into a certain amount of materials with a defined quality to be recovered. Verification of the fulfillment of recovery obligations is demonstrated through the purchase of certificates. Alternatively, individual product take-back and treatment is possible. In that case, OEMs also assume the role of waste collectors and recyclers. Full utilization of individual take-back systems is possible because OEMs can exploit the full potential of a product line in order to issue MRCs. These can be used to cover their own obligations or to sell certificates to other manufacturers. The main favorable characteristics in brief are:

- OEMs are rewarded for information campaigns about WEEE take-back because higher collection entails lower prices for certificates.
- Incentives for individual take-back and harvesting of green design efforts are stronger than under the WEEE directive, and a sophisticated measurement approach for OEM recycling duties can create a virtual design feedback loop.
- Smaller manufacturers of foreign countries are liberated from an inefficient setup of "small take-back power" in European countries. Their effort under a typical competitive market "WEEE directive" system like the one in Germany is disproportionate compared to their sales share.
- Organizational manpower for take-back aspects in each company is no longer necessary and respective costs are saved.
- Manufacturers face incentives to cut material use (dematerialization) and to apply eco-design if their recycling obligations are calculated with the help of respective software tools.

Control of the system recycling performance is in the hands of the central regulatory authority. Fine-tuning of the performance can be continuously undertaken to avoid onerous burdens for the OEMs. Stakeholder debates might lead to an agreement on a certain burden that could serve as a target for the authority. The levers of the authority are

- the assessment basis for determination of OEM obligations (material percentage and, if necessary, scoring factors).
- the minimal performance factors on a facility level.
- a price cap for the MRCs in case of a slow establishment of competition among recyclers.

Municipalities are reimbursed for their collection efforts. A compensation for this advantage is their responsibility for waste management of remaining WEEE – for which they can decide to buy additional direct MRCs. A price cap limits the cost risk for OEMs and ensures that recyclers can't abuse their enlarged scope on the value chain. Borrowing mechanisms for OEMs can serve the same goal. Banking of certificates allows for a smooth introduction phase, keeps MRCs in a reasonable price range, and avoids extreme short-term competition among recyclers. Experience with take-back behavior and other parameters can be used to raise or lower system performance targets in order to absorb MRCs or induce the issuance of more certificates.

IV. Conclusion

The design of regulation approaches for WEEE recycling has a significant impact on the ecological effectiveness and the cost-efficiency of the underlying recycling system. Current EPR implementations are characterized by different shortcomings with respect to system organization or cost aspects. The portrayed certificate market design has potentially intriguing properties with respect to both concerns. Given favorable characteristics in terms of system performance, control, organization and cost, the approach holds considerable improvement potential for all players while the same system recycling performance is achieved.

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