O-005

Ecological-value Based End-of-life Product Collecting Network Re-design and Optimization

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1 Introduction

As one of the most innovative progress in the filed of waste management, extended producer responsibility (EPR) has proved to be an effective policy instrument to motivate product/production improvements through economic incentives. However on the other hand many difficulties are reorganized in terms of policy design, product source improvement and the end-of-life products (ELPs) collecting and recycling system as well. With deeper understanding the significance and obstacle of EPR, the ecological value is believed with more consensuses to be of higher environmentally significance for ELPs collecting and recycling performance and consequently EPR policy application effect rather than traditional weigh or volume standards. Since the ELPs collecting and recycling process is the most important practical process for the application of EPR, there is quite an urgent practical need to achieve higher ecological performance through improving and re-designing current ELPs collecting and recycling systems in order to pursue a more environmentally friendly and sustainable waste management.

By taking the famous Europe EPR regulation, namely the Waste Electronic and Electricity Equipment or the WEEE as an example, this paper forwards a ecologic-value-based model for optimizing WEEE recycling operations and improving ELPs coalescing and recycling system so as to facilitate the achievement of higher ecologic value of ELPs management in a more systematic way.

2 WEEE recycling / ecological values

2.1 Practical problems

Problems with existing WEEE collecting and recycling system include both operation management aspects and technological processing aspects. As for the operation management, (1) current WEEE enacted by the EU provides too much flexibility on specific legal and structural arrangement to the Members, which leads to imbalanced development and competition differences among member countries and local producers on one hand and unexpected chaos due to unclear legal requirement on the other; (2) illegally double-charged collecting fees by some retailers, private export by recyclers and accidentally steal happened on storage spot are undeniable hindering situations to smoothly apply EPR programs; and (3) improper package and transportation conditions destroyed many reusable WEEE or decrease their recycling grade. As for the technological processing, (1) various WEEE are gathered together after collecting from distributed retailing spots which increase the material complexity to be recycled as well as the difficulties to recycle precious metal substances; and (2) though most material substances with high weight are recycled, a lot of precious metals and chemicals or those components requiring high energy to be recycled haven't yet been discomposed and recycled properly.

In fact, the last problem causes more attention since the energy and material consumed to produce those metals or chemicals are much higher than those recycled. This is actually an un-environmentally friendly situation disobeying the original goal of EPR. Failure to emphasize the ecological value as setting up collecting and recycling goals is believed to be the major cause to this situation. Improper transportation and mixed recycling operations are also hoped to be solved through more emphasizing the ecological values. To optimizing current recycling system more focusing on the concept of ecological value is just this paper's goal.

2.2 Concept and model of QUERTY/EE

The notion mentioned above that so far little notice has been given to the question whether the current developments are indeed serving the environmental goals has led to the development of the Quotes for environmentally weighted recyclability (QWERTY) concept for calculating product recyclability on a real environmental basis instead of on a weight basis only. All important elements required for environmental validation and integral costs connected to each single kind of component and materials in an ELP to be recycled are considered and calculated [1]. Related ecological value is calculated based on existing Life Cycle Assessment (LCA) method, one of the most famous of which is the eco-indicator 99 with software developed already. Taking recycling a precious metal dominated cellular phone as an example, environmental equivalent based on QUERTY calculation shows that avoiding loss of precious metal value is the most important aspect to focus on rather than the plastics recycling resulted from traditional weight based thinking.

Actually a peer chase of ecological value is not realistic especially in terms of the related producers and recyclers. Therefore, in following, this paper is going to forward an ecologic-value-based model, which combine the QUERTY concept with the economic value concept to make it possible to compare the economic and ecological contributions made by a specific recycling scenario so as to make sounder WEEE recycling decision and optimize related collecting and recycling system according.

3 Ecological-value-based models

3.1 Recycling process scenario assessment

To optimize the recycling operation according to ecological value is the first step in terms of the optimization of collecting and recycling system of WEEE. Generally, there are three scenarios for materials of the end-of-life electronic facilities: (1) reuse either entire or partial device after dismantling, (2) material recovery, and (3) landfill and incineration, as illustrated in Fig.1. In the evaluation of scenario selection, production cost for the

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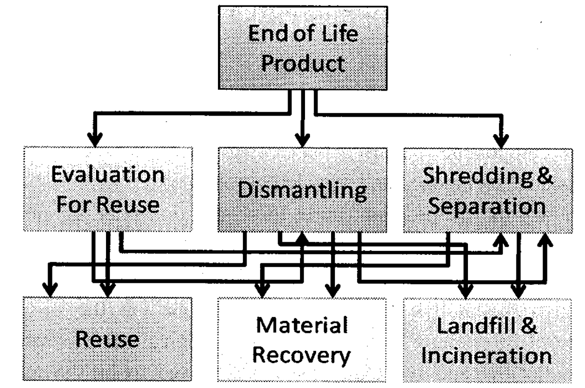

Figure 1 Major processing steps and connections in electronics recycling.

recycled appliances is evaluated through a value based metrics, which is composed of three models for computing the final output: process model, operations model and financial model. Each model handles distinct type of input parameters. Specifically, the process model has the inputs with the technical specification of the target production, outputs the processing requirements, which is treated as input for the operations model. Along with the input of operating conditions, operations model outputs the resource requirements to the financial model, which calculates aggregately the entire production cost with the input of factor prices. Explicit demonstration is shown as Fig.2.

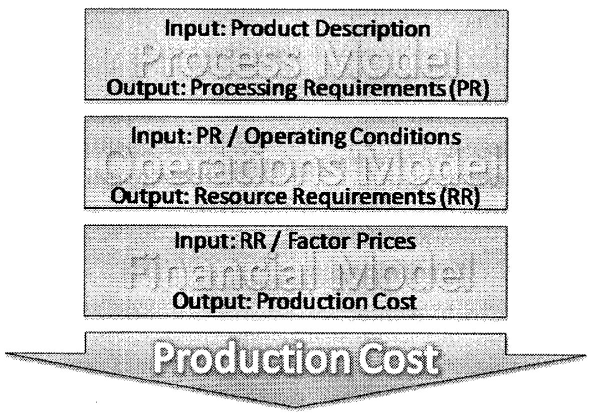

Figure 2 Definition of terms used in value-based metrics

3.2 Eco-value calculation

Both economic and ecological values of different recycling operations are considered. First we adopt the recyclability concept of value as an index for measuring the recovery of resource over time. As demonstrated in Fig.3, the evaluation at three stages is considered: (1) value at the primary market, denoted as "VP"; (2) the residual value at used stage, denoted as "VR"; and (3) the value at secondary market, which is the product of the recycling manipulation, denoted as "VP". The recovery effectiveness I_r can then be evaluated through the following equation in terms of the "Value-Added Index concept".

$$I_r = \int \frac{\sum_{i\in OF} VS_i(t-T_2-T_1)\cdot m_i - \sum_{i\in IF} VR_i(t-T_1)\cdot m_i}{\sum_{i\in IF}\sum_{j\in EM} VP_i^j(t)\cdot m_i - \sum_{i\in IF} VR_i(t-T_1)\cdot m_i}\,dt$$

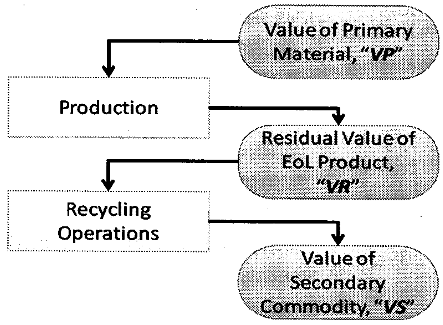

Figure 3 Process-based Cost Modeling

where, T_1 is the use time span for the raw material, T_2 the recycling operation time, "IF" and "OF" represent inflow and outflow respectively, "EM" stands for embedded material in a given flow, "m" is the specific material mass. The residue value that involved in the computation is for counterbalancing the inaccurate evaluation with respect to the quality variation of the inflow. As a result, an integrated and more systematic economic value of each recycling operation has been achieved. This calculation result is compared with the result got through QUERTY method. Different weithgt could be assigned to different result by the decision-makers according to the real situation of their produt characteristics, recycling technologies and preference about the "balance" state between the economic value and ecological value.

3.3 Collecting system optimizing considerations

Based on the above model and taking the practical problems as collecting the WEEE, the following aspects should be improved and re-considered.

Firstly, once the preferred recycling operations are decided, necessary separate collection, package and transportation should be incorporated into the excising systems. Secondly, unwanted collecting and recycling streams with unacceptable negative values/costs should be omitted/combined for higher performance. Thirdly, recycling system needs to be re-constructed due to new ecological value aims. Finally, Periodical assessment and system re-consideration should be taken in order to continuously improve the collecting and recycling system according to new EPR regulatory requirement, changed market conditions or developed recycling technologies.

4 Conclusions

An ecological-value-based model with the combination of economic costs is forwarded in this paper to optimize the recycling operations and ELPs collecting/recycling systems for higher eco-performance. By assigning the weight value as using this model, different decision-makers could combine their own economic and ecological preference, which expends application flexibility of this model.

Reference

[1] J. Huisman, The QWERTY/EE concept, Quantifying recyclability and eco-efficiency for end-of-life treatment of consumer electronic products, Ph.D. thesis, ISBN 90-5155-017-0, Delft University of Technology, May 2003, Delft, The Netherlands.