A systematical Approach on Regulating and Reducing E-Waste.

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This is the abstract

CCS Concepts: • **Hardware → Power and energy**; *Impact on the environment*;

Additional Key Words and Phrases: E-waste; Fee-Upon-Disposal Regulation; Recycling.

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1 INTRODUCTION

Nowadays society electronics has become a more and more crucial part of our lives. The demand for electronic devices increases and so does the amount of waste we produce with them. E-waste is a term used for old electronic devices that are of no use anymore and thus become scrap. This causes severe pollution to our surroundings and other countries since most of the e-waste is being exported to third world countries.

In this paper, we proposed a solution that measures the E-waste of products through governments or organizations forces manufacturers list and evaluate products *ingredient* E-waste. With this solution, the E-waste of each product P has its indicator which represented by the product features list or compoments list of e-waste:

$$\text{E-waste}(P) = \sum_i c_i$$

Where c_i is the E-waste value of i-th ingredient component of the product P, which defined by industry standard.

As a justification for this solution, we firstly investigate related works of current solutions and then established the ingredient list basic measurement requirements for the standard. Then we indicate that this study provides an exciting opportunity to advance our E-waste organizations and their regulations via two discussed example applications. Due to practical constraints, this paper cannot provide a comprehensive review of its rigorousness;

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the reader should bear in mind that the study is based on few assumptions that we interpreted in the subsequent section. Lastly, we also point out the outlooks of our solution.

2 RELATED WORK

2.1 E-Waste Related

Robinson [11] pointed out that most of the E-waste isn't even getting collected and just thrown into the household waste. 80% of the E-waste which got collected is then getting exported in poor countries. The recycling in these countries is problematic because E-waste contains lots of environmental contaminants and the facilities doesn't take proper care of this. This is why these contaminants are found around these premises. E-waste has already caused a "‘considerable environmental degradation"’[11] in these countries. Also the workers are suffering from health problems because barely protected against the dangerous fluids and gasses.

According to the current european WEEE-directive, manufacturers, sellers and distributors need to provide a return point for electronical and electrical devices. The aim is amongst others the reinforcement of recycling upon responsibility of the producer, which are also in charge of bearing the costs, while the end consumer has the responsibility of proper waste separation [5]. Specifically for smartphones, the German Goverment rejects a deposit at the expense of the final consumer on the national implementation [3]. There are also existing several non-profit projects, which accept mobile phones in order to reuse and recycle them [4, 9].

> "*Cumulatively, about 500 million PCs reached the end of their service lives between 1994 and 2003. 500 million PCs contain approximately 2,872,000 t of plastics, 718,000 t of lead, 1363 t of cadmium and 287 t of mercury*" [14]

According to [14] this already huge amount of e-waste is going to increase even further as electronics keep advancing and the need for new electronics keeps increasing. Exporting e-waste to poor countries would make sense for first world countries according to Larry Summers (back in 1991) since third world countries don't have an industry that already pollutes their air, water and ground so heavily, so they can deal with that problem more easily. Plus since mortality rates are already so high in these areas, the added pollution would not affect these countries that much.
This thinking started to change with the Basel Convention in 1989. It limits how much e-waste can be moved to what parts of the world, trying to save the environment and also trying to push the companies towards recycling.

Large household appliances and IT and telecommunications equipment made up three quarters of all e-waste back in 2002. This e-waste was mainly generated by countries of the OECD. Overall numbers are going to keep on increasing.

Although it is hard to track down how and where e-waste is going, there have to be put some restrictions into action on where e-waste is going. To solve the problem of this steadily increasing waste, recycling should become more important and more commonly used. But even for this solution, there are environmental hazards that come along with recycling.
To prevent e-waste from even becoming a problem, products should also be designed in such a way that they thrown away in a relatively short time span.

From the regulation aspect, Plambeck and Wang [10] investigates the influence of how e-waste regulation types (**Fee Upon Sale** and **Fee Upon Disposal**) and market structure (**Duopoly** and **Monopoly**) affects related four aspects of new production indtroduction: the quantify of e-waste, manufacturers' profits, consumer surplus and social welfare.

As instance, they considered the California's Advanced Recovery Fee (ARF) which is a fee-upon-sale strategy that forces customer pay for the collection and recycling of all used electronics when they buy an new product.

For analysis, their models explained the fee-upon-disposal extended producer responsibility motivate design for recyclability which is benefits for consumers but fail to reduce the frequency of new products launching.

In consequences, **optimally induces electronics manufactures to both slow research/development and design benign products** is the further challenge for our future form invention of e-waste regulation.

The EU emissions trading system (EU ETS)[13], also known as the European Union Emissions Trading Scheme, was the first large greenhouse gas emissions trading scheme in the world, and now it's still the biggest one. The EU ETS works on the "cap and trade" principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The total emissions will fall if the cap is reduced over time.

Under the "cap and trade" principle, a maximum (cap) is set on the total amount of greenhouse gases that can be emitted by all participating installations. "Allowances" for emissions are then auctioned off or allocated for free, and can subsequently be traded. Companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. Trading brings flexibility that ensures emissions are cut where it costs least to do so. A robust carbon price also promotes investment in clean, low-carbon technologies.

Installations must monitor and report their CO2 emissions, ensuring they hand in enough allowances to the authorities to cover their emissions. If emission exceeds what is permitted by its allowances, an installation must purchase allowances from others.

The system covers the following sectors and gases with the focus on emissions that can be measured, reported and verified with a high level of accuracy: carbon dioxide (CO2), nitrous oxide (N2O), perfluorocarbons (PFCs).

According to the European Commission, in 2010 greenhouse gas emissions from big emitters covered by the EU ETS had decreased by an average of more than 17,000 tonnes per installation from 2005, a decrease of more than 8 percent since 2005.

One way to reduce e-waste is by successfully recycling outdated devices. There have been many proposals for this. For example, Kahhat et al. introduced a system similar to the "bottle bill", which enforces recycling. A consumer has to pay an additional deposit when buying new devices, which are returned on successful return [6].

People are facing a hazardous problem in the modern era, more specifically saying, there are 20-50 million tons of e-waste being produced per year around the world, and this trend is still keeping going up. [12]

The e-waste originally appeared in the developed countries, but now expanded to the developing countries, even less developed countries, which brings them both advantage and disadvantage.

The reason why e-waste has such contradictory traits mainly lies on the two aspects of e-waste, which are supposed to be treated respectively:

- Poisonous parts in the e-waste.(disadvantages)
- Valuable parts in the e-waste.(advantages)

Therefore, how to maximize the advantages, meanwhile minimize the disadvantage becomes a priority for those suffering countries.

Traditional ways to deal with e-waste will consist of four procedures: Recycling, Landfills, Composition of e-waste, and Security issues. The paper also provides several approaches: Life Cycle Assessment, Material Flow Analysis, Multi-Criteria Analysis , Extended Producer Responsibility, Health Implications.

A good management system should apply above approaches into procedures. How can we innovate over the traditional method and put forward a more scientific and efficient way could be a interesting proposal for our final project.

2.2 System Currently

There are already some existing E-Waste system. For example, the EWSI is a company that offers customized end-to-end solutions in IT Asset Recovery, E-Waste Management, and Electronics Reverse Logistics. It can provide a variety of containers for onsite collection, audit and asset registration services on pickup, and either dedicated or consolidated routes and storage prior to processing. Their E-Waste system can also provide site clearance and decommissioning services.

To close the electronics loop, EWSI takes the residual e-waste streams after refurbishment and component harvesting (as well as any whole assets designated for destruction by their owners) and uses state-of-the-art engineering to break these down into segregated material streams for processing, refining, and maximum extraction to produce new manufacturing input.

The EWSI's E-Waste system operates with a zero-landfill objective and uses a variety of processes to generate up to twenty different streams of recyclate that are converted into new raw materials by intelligent and environmentally friendly downstream refining. They recover maximum value from these materials, including glass, plastics, ferrous and non-ferrous metals, precious metals, and platinum group metals.

EWSI offers the highest standards in data security. That provides custom solutions, using in-house resources or those of their affiliate network, based around the following processes: DOD-compliant overwriting, degaussing, encryption, long-term storage and physical destruction. Their collection and transportation services are secure and transparent.

Another example is from the U.S. which is establishing the importance of developing public response for E-Waste system and the U.S. has already legislated and implemented electronic recycling systems. Several tools including Life Cycle Assessment (LCA), Material Flow Analysis (MFA), Multi Criteria Analysis (MCA) and Extended Producer Responsibility (EPR) have been developed to manage e-wastes especially in developed countries[7]. Currently, different systems for different kinds of E-Waste system have been implemented and used. A beverage container recycling program, commonly referred to as a âĂIJbottle bill,âĂİ is one important example of a successful deposit-refund system. The âĂIJbottle billâĂİ is a system that encourages consumers to return beverage containers by providing a refund on the deposit, and this system is considered by many stakeholders as a successful recycling program that should be expanded as a federal policy. The refund value of the container provides a monetary incentive to return the container for recycling[6]. This is a very good solution for the design of new E-Waste system.

3 INGREDIENT LIST SPECIFICATIONS

In order to help determine how much e-waste is exactly being wasted we want to introduce an ingredients list system similarly to the EU legislation used for food products[2]. Electronics manufacturer would be obligated to hand out a list with each electronic product to show how much and what kinds of raw material they use. Based on this a very precise set of rules and regulations can be created.
Before this we have to be create an ingredients list with specific demands.

3.1 EU Regulations For Ingredients Lists

According to [1] there is a very specific set of rules that an ingredient list for food should be a aware of. For example the ingredients should be ordered by weight. The more a certain ingredient was used for making the food, the further on top of the list it should be. This makes the first item of the list the most used ingredient and the last item is the least used one. This makes it very easy to spot what the main ingredient is.

To increase transparency even further, the weights of some ingredients have to be listed very precisely. According to [1], if the manufacturer advertises certain ingredients on the packaging, he has to indicate how much of

grade	range	tax rate(%)
1	under 1000 ton	5
2	part from 1000 to 2000 ton	10
3	part from 2000 to 4000 ton	20
4	part from 4000 to 8000 ton	30
5	part exceed 8000 ton	35

Table 1. Template table to tax hierarchy

these advertised ingredients are contained percentagewise. Furthermore a set of certain ingredients always has to be listed with their respective weight portion of the product. Ingredients like sugar or fat fall into this category. Special food additives not only have to be listed as an ingredient but their purpose also has to be made clear. This way the user knows why these unknown to him ingredients do. Food additives can also be listed as E-numbers.

Further laws for these ingredients lists are in action but mentioning these is not necessary at this point. This excerpt should only give a rough overview about how ingredients have to be listed on products.

3.2 Our Ingredients List

Our ingredients list for electronic devices will have a lot in common with those demanded by the European Union. Obviously there have to be some differences since we are dealing with electronic devices.

We will transfer the ordered list to our use case. There will be a list of all materials used in each electronic product. The very first material in this list will be the main ingredient and the last one will be the least used ingredient. Everything in between is ordered accordingly.
Special materials have to be brought to attention either by underlining them or making their font bold. Furthermore there has to be a very precise indication of how much of each of these materials are being used by weight. Materials that fall into this category are either especially dangerous to the environment, rare materials or materials that are hard to recycle.

All other materials do not have to be indicated by weight. They will fall into the category of e-waste but are considered not to be especially dangerous to nature or humans. Their weight portion can be calculated by subtracting the weight of all of the specially indicated materials from the indicated total weight of the product itself.

4 APPLICATIONS

4.1 Tax and Prevention Mechanism

A mature electrical product could consists of thousand small parts. In order to better calculate the e-waste tax for each product, we should primarily order all the materials in the ingredient list as a vital factor to decide how much e-waste they could generate. We set a staircase-like structure to distinguish different tax rate, and it could range from 5% to 35% in 5 grades. Moreover, the degree of contamination to environment for each individual product is also estimated to get a flexible tax rate, which means more contamination-prone materials inside a product, the higher tax rate this hierarchy holds.

By means of above table, if the industries want to produce more products in which the material could damage to the environment, we have an instruction to decide how much they have to pay more.

The more important thing is how can we prevent the industry to lie about the ingredient list. We put forward an incentive mechanism. The cost of execution of ingredient analysis and the penalty of avoiding regulation under government. We leverage the Game Theory for the industry to get the maximum of profit.

The Government takes responsibility to protect the resource and environment, which on the on the one hand could be understood that if the industries do not want to execute the publishing of ingredient list, it leads to the contamination, so that the government has to take the remedial measurement, let us assume that this cost is R, at the same time it takes the government regulation cost C to penalize the industries with cost F that the industries have to pay for the government. In order to let each Industry execute the list consciously, $F - C > 0$; On the other hand, when the Industries are willing to execute the ingredient list, it brings the healthy to the public back, so that the welfare W comes sequentially.

Suppose the selling price of normal electronics is P_n, the electronics with ingredient list is P_{il}. The cost of normal electronics in C_n, and the electronics with ingredient list is C_{il}. The profit for each execution of ingredient list should be $R_{il} = (P_{il} - C_{il})$, inversely, the profit is $R_n = (P_n - C_n)$. Since we have the regulation cost, so the government take the regulation at the Îś probability, so it occurs at $(1 - \alpha)$, when the government will not do anything. On the other hand, for the industry itself, it holds β probability to decide execute the ingredient list.

So we get following game matrix table

Leveraging all variables we have defined, we could get the Expectation value of government:

$$E_{il} = \alpha\beta(W - C) + \alpha(1 - \beta)(F - C - R) + (1 - \alpha)\beta W + (1 - \alpha)(1 - \beta)R$$

Analogously, the Expectation value of Industry:

$$E_c = \alpha\beta R_{il} + \alpha(1 - \beta)(R_n - F) + (1 - \alpha)\beta R_{il} + (1 - \alpha)(1 - \beta)R_n$$

According to the [8] analysis, we calculate the equilibrium solution for this Game Theory Model, and then we get optimal response functions for each entities (Government and Industry).

$$\alpha = \begin{cases} 0 & \text{if} \quad \beta > \frac{F-C}{F} \\ [0,1] & \text{if} \quad \beta = \frac{F-C}{F} \\ 1 & \text{if} \quad \beta < \frac{F-C}{F} \end{cases} \tag{1}$$

$$\beta = \begin{cases} 0 & \text{if} \quad \alpha < \frac{R_n - R_{il}}{F} \\ [0,1] & \text{if} \quad \alpha = \frac{R_n - R_{il}}{F} \\ 1 & \text{if} \quad \alpha > \frac{R_n - R_{il}}{F} \end{cases} \tag{2}$$

The intersection of two response functions is the mixed Nash equilibrium of the government regulation during the execution of Ingredient List. Finally we get the unique deterministic solution, that is

$$\alpha^* = \frac{R_n - R_{il}}{F}$$

$$\beta^* = \frac{F - C}{F}$$

Which means the Government is intended to regulation the Industries at the probability of α^*, and the Industry execute Ingredient List at the probability of β^*, none of them should not change this balance state unilaterally, otherwise one of their profits could be damaged.

4.2 Ecosystem of Recycling

Kahhat et al. proposed a "deposit-refund system" [6] for the successful collection and recycling of e-waste. In this economic system the consumer has to "pay a deposit on purchase, a variable portion of which is returned when turned in at the end-of-life" [10]. The interest collected by this deposit will compensate for overhead costs such as transportation and storage fees of recycling-companies. Moreover, as the returned deposit can vary, recycling companies with better recycling processes, can offer a higher return to consumers, as they will still gain revenue for the resources in recycled products. This system does not only ensure the return of e-waste by consumers, but also favors companies, who can recycle more effectively.

Wowever, one huge downside of this system is the requirement to track to-be-sold devices, as the deposit is linked to the device. With our solution of an ingredient list for all released devices this requirement could be avoided. We would eliminate the deposit (and with that the tracking) and collect additional tax, when purchasing electronics. Moreover, consumers will be able to sell their e-waste to recycling companies refunding their tax payment in the process.

Another important advantage of the ingredient list is that, recycling companies know the contents of a device and as such could concentrate on specific recycling processes. Another weakness of Kahhats et al.'s system [6] is that, a company alone would not be able to recycle a product completely - however, recycling companies could negate this by selling partly recycled products to each other. The specialized companies, which would be possible by the ingredient list, would allow this selling process.

With the collected tax the government could support the establishment of recycling companies and in general the ecosystem of recycling dynamically. This offers huge flexibility, which is required in the area of electronics, as this market is a ever changing one. With the release of ingredient lists, the government can determine, which resources will be needed for production and as a result for recycling. Thus, the government can subsidize effectively and visionary.

To sum up, the ingredient list could eliminate critical weaknesses of Kahhat et al.'s system, while also offering new possibilities.

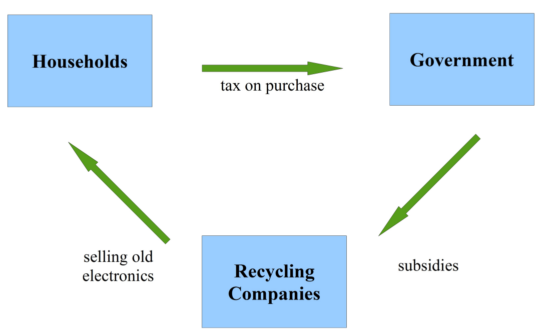

Table 2. Cashflow of this system

5 PROBLEMS

At first, many producers of electronics may struggle to fulfill this law when their products contain parts delivered by other companies. It would take some time for all the producers to prepare the exact contents of their products.

This may increase the price of the product, either because the producer has additional expenses for this or because they just might not do it if the market is too small.
To be as precise as possible is very important for this approach, especially when the devices are very small and the components contain only grams or milligrams of certain declarable substances. The wanted precision might not always match a feasible one. The determination of the precision of the declaration could be very difficult and therefore has to be explored with care.
A disadvantage of this system could concern importers who import non-labeled electronics which weren't originally designed for the European market. It would be the importers duty to label it himself but mostly this is non-trivial or even impossible. The penalty the importer had to pay would increase the final price for the consumer which is bad for both the consumer and the economy. This problem will persist during the enrollment of this law but may fade with time when producers have caught up.
One may argue also that it's quite complex to verify the lists the companyâĂŹs made and to control the implementing manufacturers. This is because of the volume of devices to control. This problem increases when financial benefits are tied to the contents of these lists. To work out a solution to this is the task of the corresponding government. The problems of this approach arise primarily from the context where it is implemented (see 4.2).

6 OUTLOOK

As our proposed system of a ingredientlist for electronic equipment and devices is only a theoretical construct, as a first next step it is necessary to test it under real conditions. It is important to find out the practicability of the mapping of food related ingredientlists on electronical related ones. This largely depends on the application and has to be evaluated for every specific use case.

In general, more application models can be developped considered, which also could require different specifications of the ingredientslist. For example the sorting of the list may be necessary to adjust: If the emphasize is on toxic materials, the order of the ingredients maybe should be oriented towards this criteria instead of the weight of all used materials, is the focus on special rare materials in order to boost their recycling and so save resources, it is more intuitive to give them a higher priority in the listing of ingredients. Also further other questions can appear: Is an extended labeling of the grade of toxicity necessary instead of just marking all toxic materials in the same way? What else has to be integrated on the ingredientlists (e.g. e-plastic)? Where are the limits of the system (potential need of labeling all components with a ingredientlist for partly recycling/resale)?

It is also important to evaluate all effects of such a list as our proposed one. Potential influences on different several aspects has to be considered and analyzed one by one. For example there could be negative impacts on the economy: The list can be misconceived by end-consumers and lead to a significant decrease in consumption. Or the establishment of our ingredientlist could lead to a disadvantage of the european market against markets, which do not need to fulfill their requirements. Against that, our list could also rise the awareness of the public for the need to recycle. In general, all advantages of our system have to be evaluated in reality, so they can be weight up to negative side effects and disadvantages.

We think, our proposed ingredientlist holds great potential. It provides a measuring system for e-waste, can raise general awareness in the consumers mind and so on. It provides the basis for further laws regarding the e-waste problem. This also includes to identify and distribute responsibilities to the different layers of EU government, organizations, producer and the consumer for both evaluating the ingredientlist itself as well as developing and executiing further rules based on the ingredientlist.
Is the latter once performed, then it is possible to draw comparisons between the resulting system and the e-waste managing systems mentioned in our related work section (see 2.2). Moreover, it is possible to think about ways,

how these systems can be combined. Therefore is is neccessary to identify all benefits of the existing systems, which would have gone beyond the scope of this work.

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