International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:12, No:10, 2018

Comparison of E-Waste Management in Switzerland and in Australia: A Qualitative Content Analysis

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***Abstract*—**E-waste/Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams across the globe. This paper aims to compare the e-waste management system in Switzerland and Australia in terms of four features - legislative initiatives, disposal practice, collection and financial mechanisms. The qualitative content analysis is employed as a research method in the study. Data were collected from various published academic research papers, industry reports, and web sources. In addition, a questionnaire survey is conducted in Australia to understand the public awareness and opinions on the features. The results of the study provide valuable insights to policymakers in Australia developing better e-waste management system in conjunction with the public consensus, and the state-of-the-art operational strategies currently being practiced in Switzerland.

***Keywords*—**E-waste management, WEEE, awareness, pro-environmental behavior, Australia, Switzerland.

I. Introduction

E-WASTE or electronic waste/scrap or WEEE derived from obsolete electrical and electronic equipment (EEE) is one of the fastest growing waste streams all over the world. According to the solving the e-waste problem (Step),

> "E-Waste is a term used to cover items of all types of EEE and its parts that have been discarded by the owner as waste without the intention of re-use" [1].

In 2016, global EEE consumption reached 60 million tonnes (Mt) [1]. Recent research report "Global E-waste Monitor 2017" by United Nations University (UNU) estimated that in 2016, total e-waste generation was 44.7 Mt which was mainly generated in Asia, North America and Australasia region [2]. Due to complex material structure, e-waste is an important waste stream as it contains numerous valuable materials such as gold, silver, platinum, palladium as well as several toxic elements such as cadmium, lead etc. Effective and environment-friendly efficient e-waste collection and disposal is a complex task that involves various actors (i.e. government, product manufacturers, recyclers and other agents). Globally, developed countries have taken sustainable and long-term solution tackling the overwhelming problem. According to the EU WEEE Directives 2012/19/EU Directive, there are clear distinctions among the product types, recovery and recycling targets. Table I shows the details of the basis of e-waste collection and recovery requirements for the member countries. This table also shows the revised classification of the e-waste (in 6 categories) which will be effected from 18 August 2018 [3]. At present, EEE products covered under the directives (in 10 different categories) can be found in the Annex I of the legislative document [4]. However, there are some countries in the OECD, where there is a need to improve current management structure and characteristics based on the internationally successful system.

It is to be noted that Switzerland is the first country in the world that successfully manages e-waste collection and recycling system before some of the other regulations such as EU WEEE Directives Directive 2012/19/ EU [5]. On the other hand, in Australia, National Television and Computer Recycling Scheme (NTCRS) came in to force in 2011, and successfully diverted thousands of tonnes of e-waste from landfills [6]. However, it is particularly interesting to see what the current scope of improvement present in the Australian system comparing on Swiss e-waste management system and public understanding of the e-waste management system in Australia.

The aim of the paper is twofold. First, it compares the e-waste management system in Switzerland and Australia and second, it presents some results from a survey on customer awareness about e-waste in Australia. Comparison of the system provides detailed characteristics of the system and identifies critical issues that need further attention to the policymakers improving the Australian e-waste system. To validate such need, the survey results provide how and what needs to be done refining the current architecture of the e-waste management system in Australia.

TABLE I
Revised E-Waste Classification according to EU WEEE Directive 2012/19/EU, Adapted from [3]

Category	Type of the product	Recovered (%)	Re-use or Recycled (%)
1	Temperature exchange equipment	85	80
2	Screens, monitors, equip. with surface screens >100 cm^2	80	70
3	Lamps	-	80
4	Large equipment	85	80
5	Small equipment	75	55
6	Small IT and telecommunication equipment	75	55

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The research method of this study is qualitative content analysis. With the method, various documents such as regulation and policy papers, recycling company reports and published journal articles were collected and analyzed for this study. Besides, a questionnaire survey was conducted in Australia regarding the public perception about e-waste.

II. E-Waste Management System in Switzerland

A. Background

Switzerland is the second highest gross domestic product (GDP) per capita (according to purchasing power parity) income country in the European Union (EU). The current population in the country is 8.2 million and more than 94% of the households have a personal computer (PC) [4]. This gives an indication of the total number of installed PC within the household level is over 3.5 million [7]. 93% of the households have TVs and 86% of the household have dishwashers. Swiss households are very well-equipped with IT hardware as well (97% of the households have mobile phones) [8].

Environmental sustainability issues are quite crucial for the government as well as for the public. In the year 2018, Switzerland ranked number one in the Environmental sustainability index [9]. Customer awareness about environmental issues is ensured with extensive participation and in the design of several important strategies such as air, water, and waste management [10]. According to Joos W. [11]

> *"Contributions to the development of waste management in Switzerland show that decision transparency, interregional cooperation, information policy and public participation are important factors with regard to the public acceptance of waste management in Switzerland".*

Better recycling is one of the priorities of the government as well as to the public and numerous systems have been developed in segregating waste fractions such as glass, paper, plastics bottles etc. in the country [12]. As mentioned earlier, E-waste is a growing environmental problem in the world and developed country like Switzerland is managing this waste stream in the most successful way for the last two decades before some of the prominent e-waste management regulation such as EU WEEE Directive started. In fact, it is the first country that developed a regulatory instrument based on extended producer responsibility (EPR). In the year 2017, Switzerland processed total 122,800 tonnes of e-waste and the recycling rate for the waste is 73% [13].

In such aspect, per capita collection of e-waste in the country is more than 15 kg which is almost quadruple of the EU target of 4 kg/capita.

This tremendous success is being achieved by engaging four producer responsibility organizations (PROs) – SWICO, SENS, SLRS, INOBAT; in the entire e-waste collection system. SWICO is responsible to collect all the IT equipment and brown goods (i.e. televisions, radios etc.) while SENS collects large household items, for instance, "white goods" - refrigerators, microwaves, washing machines etc. SLRS is connected to the SENS and major fractions of the lighting equipment type e-waste is collected. These PROs were established based on the EPR principle and according to Organisation for Economic Co-operation and Development (OECD) "Extended Producer Responsibility (EPR) as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's lifecycle" [14]. EPR was implemented well before the official e-waste-related regulation "The Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment (ORDEE)" came into force in the year 1998.

B. The Architecture of the E-Waste Management System

Collection and recycling of the e-waste management system in Switzerland is an organized take-back system that ensures the participation of all the manufacturers, importers, retailers/distributors, recyclers and most importantly the customers. As mentioned earlier, with the implementation of the EPR, Swiss e-waste management system is managed both legally and operationally. Importers and manufacturers of the products take physical and financial responsibility for the entire system. The PROs work on behalf of the group. This creates a healthy relationship among the members of the manufacturers and importer with the e-waste management authority as well as demarcate clear role and responsibilities. Fig. 1 shows the physical and financial flow of the take-back system.

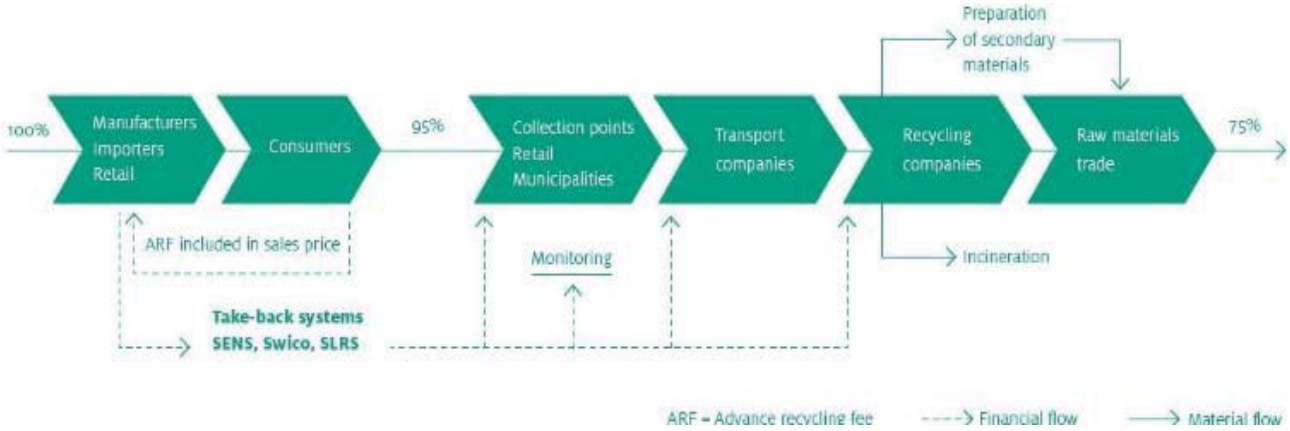

Fig. 1 The physical and financial flow of e-waste management system in Switzerland [13]

By regulation, customers are obliged to return their end-of-life (EOL) items to the designated collection points regardless of the product brand and product types. Retailers must collect returned items from the customer, free-of-charge. This incentive is collected from the customer under the mechanism of Advanced recycling fees (ARF) charged at the sales price of a product. This fee is used for all the operation in the entire e-waste management system: collection, transportation, and recycling. The ARF is found as an effective financing mechanism that guarantees that PROs run the operation smoothly and have the capability facing challenges in the future. ARF is only applicable when the disposal cost is higher than the value of recoverable materials. SWICO management team set the recycling fees by "product price index" by which recycling fees are calculated [5]. As of 2018, for consumer electronics, the recycling fees vary from 0 Swiss Franc (CHF) to 28 CHF (including VAT), same as e-waste generated from IT equipment. The VAT amount for EEE items is around 7.7% in Switzerland. Table II shows the financial balance sheet in the year 2011.

TABLE II
INCOME AND EXPENDITURE OF THE SWISS E-WASTE MANAGEMENT SYSTEM IN 2012 [15]

Total income (in million CHF)	**31.70**
Expenses (in million CHF)	
Recycling	10.20
Transport and logistics	8.20
Collection points	4.50
Audits, analyses, PR, operating expenses	1.80
Disposal of packaging	3.30
Disposal of batteries	0.6
Securities reserve for fluctuations	0.5
Latent waste disposal obligation	1.40
Staff costs	0.89
Total expenses (in million CHF)	**31.39**

It is seen from the table that the largest portion of the income went to the recycling operation, around 10.20 million followed by transport and logistics 8.20, for the year 2011. At present, there are 6000 collection points (39% of the total collected through this channel), nationwide with over 12000 retailers. Besides, collection points, retailers are also playing a significant role in the collection system. 40% of the collected e-waste comes from retailers. PROs share the same collection points that ensure to manage the logistics, benefits from economies of scale and provide customer-friendly solutions. Around 4.5 million CHF was spent on collection points in the year 2011. From both the income and expenditure figure, it is said that the operation ran in break-even point while maintaining sound environment-friendly disposal of e-waste items.

From the Fig. 1, it is also found that for the smooth functioning of the system, multi-level monitoring and control is implemented. This prohibits free-riding (e.g. getting benefit from a system without paying fees for the services) by tighter control over inventory at the downstream and maintains the environmental standard of the recycling and sound disposal. This also ensures the participation of stakeholders (i.e. retailer, customers etc.) in the system. Currently, Swiss system runs by the EN 50625-1:2014 family of standards SN EN 50625 and in-accordance of State-of-the-art. According to Article 3 of the ORDEE 1998,

> *"State-of-the-art is understood to be the most recent stage of development of a technical process which: a) has proven itself on comparable installations in Switzerland or abroad, or that has been successfully applied in tests and that the technique allows transpose to other facilities; and b) is economically bearable for a medium and economical business the branch concerned".*

Transboundary movement of e-waste is prohibited according to the Basel Convention Ban Amendment and Switzerland banned the export of e-waste to non-OCED countries.

Transparency in processes such as collection, financing and contracting helps to alleviate the potential monopolistic behavior of the PROs. PROs are the non-profit organizations and it ensures the participation of the producers of EEE items. ORDEE only provides the guideline for managing the e-waste but it is the producers that decide in which PROs they want to involve with. Participation in the PROs is voluntarily not mandatory and producers are actually benefited by the economies of scale. As of 2016, there are 80% dismantling companies working in Switzerland. With the processing, approximately 30,000 tonnes of E-waste was processed [16]. PROs maintain the competitive recycling market because the largest part of the cost of the whole system is being used for the recycling purpose. In such a context, SWICO and SENS initiate several steps to ensure the transparency preventing the monopoly of the recyclers. As of 2018, there are total 11 licensed recyclers of SWICO and 22 for SENS. Swiss Lighting Recycling foundation (SLRS) generally used the recycling partners for their product recycling. There are total 11 recyclers who work both SWICO and SENS. Competition among the recyclers is ensured by continuous observation of the system and dialogue.

III. E-WASTE MANAGEMENT SYSTEM IN AUSTRALIA

A. Background

Australia ranked 28 with an estimated GDP/capita of $49,900 in the year 2017 [17], and one of the highest per hour wages rate in the world. Over the years, with the increasingly high level of income, purchase of EEE especially, television and IT equipment purchases have increased dramatically, and the market share of several multi-national companies is quite high in the country. The number of working television sets reached 18.7 million in the year 2015 [18] and 91% of the households are connected to internet with desktop or laptop computers [19]. Furthermore, in the year 2016-17, around 95% of households have a mobile/smartphone while 93% own either desktop or laptop computers. In 2015-16, total currency spent on ICT reached $6.2 billion in the country [20].

With the increased living standard, the country is producing a significant proportion of the waste across the various sector. In 2014-15 Australia produced about 64 million tonnes of

waste, which is equivalent to 2.7 tonnes of waste per capita. However, according to the Australian National Waste Report 2016 [21], providing better waste education to the public is one of the areas that needs further attention.

E-waste is one of the escalating waste streams in Australia. As of 2016, 0.57 Mt of e-waste was generated in the country which is 23.6 kg/capita, one of the highest per capita e-waste generation in the world [2]. It is also reported that up to 2008, 17 million televisions and 37 million computers have been sent to landfill [22]. To divert the increasing amount of e-waste, in 2009, Australian government established National Waste policy 2009 under which waste management policy was updated. To consider e-waste management issue, with the policy integrated with EPR and Product Stewardship (PS) and regulatory framework, in 2011, the Product Stewardship Act 2011 was established. According to Morris et. al. [23]

> *"the Product Stewardship Act 2011 in conjunction with the Regulations and the National Television Computer Recycling Scheme (NTCRS) provide the framework to manage the lifecycle of computers, televisions and their peripherals".*

The purpose of the scheme is to increase the recycling rate of the waste television and computers generated each year instead of landfilling that creates detrimental environmental impact due to the presence of the hazardous substance. At this moment, there are total 1800 collection sites all over Australia and in the year 2017, a total of 51687 Mt of materials were recovered with an average material recovery rate of 95.85%.

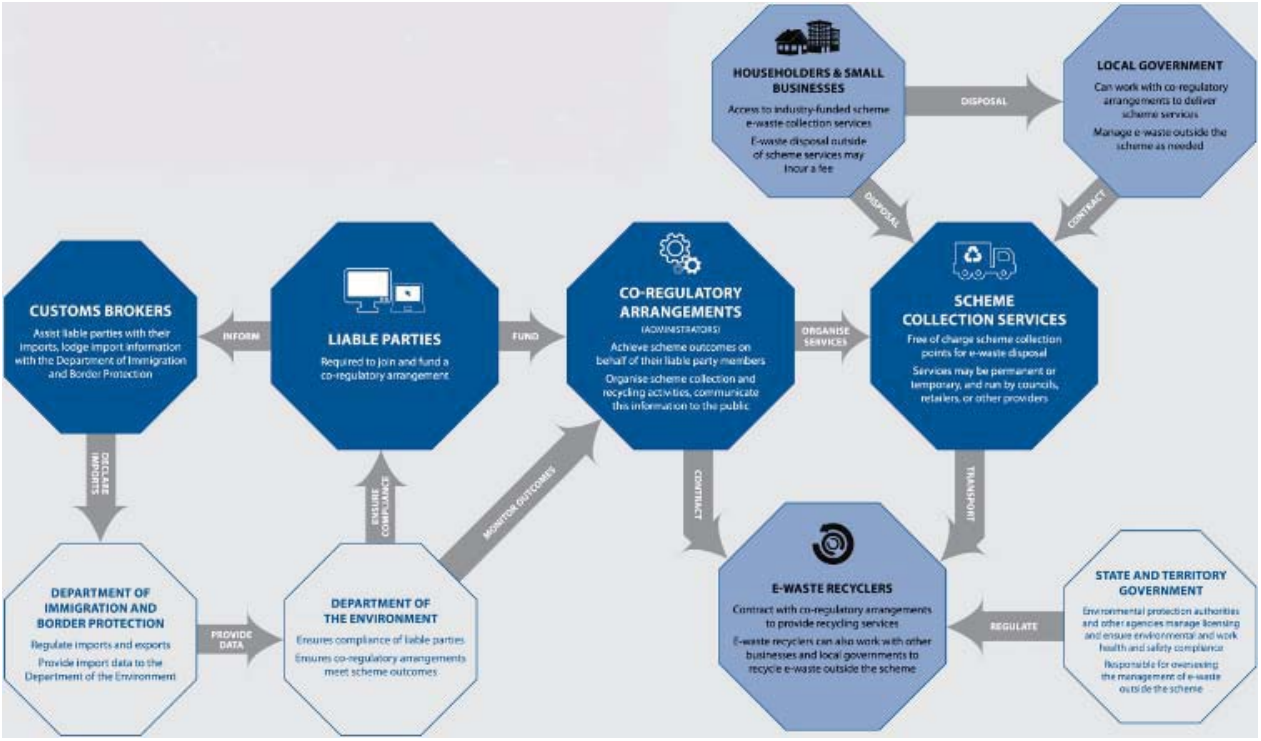

Fig. 2 Roles and responsibilities of the actors in the National Television & Computer Recycling Scheme (NTCRS) [26]

B. Overview of the E-Waste Management System

Collection and recycling of e-waste (mainly TVs (LCD, CRT LED), computer (both laptop and desktops) and computer peripheries) are being managed in the NTCRS where the funding is coming from the industry. Here, industry refers to the group of importers, manufacturers, distributors who are the first actor in the forward supply chain dispatching the products to the customer. These actors are called liable parties in the system. Australian E-waste management system is a combined example of Swiss (role and responsibilities of the participants), Japan (material recovery target issues) and EU WEEE regulation (for recycling and collection target) [23]. Liable parties (industry partners) are responsible for financing environmentally sound disposal of the e-waste. The Department of Immigration and Border Protection and Department of the Environment are the two legislative bodies that directly act as the regulatory bodies in the system. Fig 2 shows the roles and responsibilities and key participants of the e-waste management system in Australia. Record of import data for calculating the amount of waste arising, ensuring compliance of the liable parties are the two critical roles that the Departments play. Both the departments as well as the liable parties are directly connected with the co-regulatory agreements (CRAs) who work as the administrators of the system to achieve the scheme's outcome (i.e. achieving 90% material recovery rate). Liable parties provide funding to the CRAs and at present, there are four CRAs present in the system (e.g. Australian & New Zealand Recycling Platform Limited (TechCollect), Electronics Product Stewardship Australasia (EPSA), E-Cycle Solutions Pty Ltd and MRI PSO Pty Ltd (Drop Zone)). There are total 31

recycling facilities that are currently actively working under the CRAs [24]. However, there are other recyclers available in the country whose participation is not mandatory under the scheme.

State and territory government participate in the scheme as a voluntary basis (no obligation by regulation). Likewise, customers (mainly households and small business) do not bear any responsibilities (neither physical not financial) for the system. At present, the material recovery rate is fixed at 90% and recycling target being 50% which will be increased to 80% by the year 2026-28. Although significant achievement has been made by the NTCRS, however, funding mechanism and incentives for local material recovery facilities are not clear [24]. Moreover, there is hardly any data on public understanding on how the system works and what are products covered under the scheme. Although, NTCRS is currently running under the "Collection, Storage, Transport and Treatment of Used Electrical and Electronic Equipment, Standard AS/NZS 5377, 2013", it is reported that currently, all the recyclers are operating at low technology and labor incentive processes. The recyclers who are using such kind of technology are called as first stage recyclers. Further downstream recycling for valuable material recovery for the case of Australia is generally being done by the overseas recycling companies [25]. China, Hong Kong, Japan, India, Indonesia, Singapore, South Korea and Thailand are the major importing countries of Australia's TVs and computer waste.

IV. Comparison of the System

It is difficult to compare the two systems as e-waste management in Switzerland is being operated successfully for the last two decades whereas the Australian system is comparatively new. If we take a look at the e-waste scenario and other related information on population and GDP, then it would be more reasonable to compare. Table III shows the e-waste scenario in the two countries. In terms of geography, Australia is almost 188 times bigger than Switzerland and population density is 67 times less than Switzerland. However, it is expected that by 2056, the population will increase to between 30.9 and 42.5 million people in Australia. In terms of E-waste generation, both the countries showed exceptional figure. Although population is less in Australia, the e-waste generation is comparatively high in the country. This means that to catch up with the future generation of e-waste, government and responsible authorities need to take adequate measure in adjusting policy and operational issues of the current system in which Switzerland's experience would be valuable. In this study, we compare the systems according to some key issues which are given Sections IV A-D.

A. Legislative and Policy Initiatives

ORDEE of Switzerland mandated objectives that e-waste will not mix with the municipal solid waste and environmentally sound disposal of the e-waste must be done through the PROs based system. It is to be noted that Switzerland is one of the countries where a substantial amount of municipal solid waste (MSW) goes to waste-to-energy incineration plant for electricity production. As e-waste contains major polymer plastics, burning of such element will definitely impact the surrounding environment. For that reason, Switzerland gave a proper indication of the objectives in the ordinance. For Australia, there are no objectives set in the Product Stewardship Act 2011 which was the basis of NTCRS. According to Morris [23], Switzerland fulfilled the regulatory objectives by developing supporting policies and instruments and making a direct relationship between public and industry partners (i.e. manufacturers and importers). Product specific requirement and specification is mentioned in the Swiss system which covers all the six categories mentioned in Table 1 while Australia considers only TVs and computer. Economies of scale (e.g. stable supply of a large amount of product) is an important factor for sustainable e-waste recycling operation and without considering small and consumer equipment in the e-waste stream, it will be challenging for Australian local recyclers to survive in the near future. Furthermore, it is assumed that vast amount of small and consumer items is going to landfill like previously as customers in Australia do not have any provision to drop their product off to designated collection points and/or retailers considering this specific product. This is completely opposite to the Swiss system.

TABLE III
E-Waste Scenario in Switzerland and Australia [27]

Indicator	Switzerland	Australia
Population (total inhabitants in million)*	8	22.68
Purchasing Power (USD per Inhabitant)*	45,286	42,354
EEE Put on Market (kg per inhabitant)*	28.2	24.6
EEE Put on Market (total in metric kg tonnes)*	226	559
E-waste Generated (kg per inhabitant)**	26.3	20.1
E-waste Generated (total in metric kg tonnes)**	213	468

B. Financial Mechanism and Monitoring of the System

Swiss e-waste management system implements economic, informative, regulatory and administrative instrument while Australia's approaches are regulatory, institutional and administrative [23]. There is no financial/economic instrument present in the Australian system that monitors and oversee funding mechanism. Moreover, in the reporting outlet (published jointly by the SWIOCO, SENS, and SLRS) of the Swiss system, there is a financial balance statement which was not found in any of the reports provided by the CRAs. In the Swiss system, wherever ARF goes to an actor, (for example, top the recyclers, PROs etc.), it is monitored and the participant must report the financial activity. This ensures getting rid-of free-riders from the system.

C. Role and Responsibilities

In the Swiss system, it is mentioned in the Article 5 "*Anyone who intends to discard a device or component is required to return it to a trader, a manufacturer or a disposal company*". Customers, regardless of where they come from (households or small business), each entity must dispose of their waste in the designated collection and/disposal points. This ensures the participation of the disposers. But surprisingly, customers are not obliged to return back their product and they can dispose of according to their will, in Australia. It is not surprising in

Australia that a laptop has been disposed of in the regular garbage bin (yellow bin that is being said as recyclable). On the other hand, local government plays a significant role in the Swiss management system in a sense that most of the collection points are located in the municipalities/public amenities (train station, supermarket etc.) and local councils are the most important actor in the system which facilitates efficiency in collection of e-waste on a mandatory basis. In the Australian system, local government does not have a mandatory role to play and all their activities were made voluntary and under the condition of "if required". "It is important that local councils are aware that scheme services can run without council involvement and still deliver benefits to local communities (e.g. collections through retail outlets)", this is indicated in the scheme for local government. To ensure reasonable collection points access for customers, local government should play an important role, as they are the best actor who can provide solutions to ensure 100% reasonable access for all other stakeholders.

D. Collection and Recycling

Collection and transportation are critical issues in a waste management scenario. Although population density is less in Australia compared to Switzerland, the number of collection points are very inadequate. In the Swiss system, one collection point is designated for only 444 which is 12, 777 in Australia. So, adequate number of collection points in all geographic areas (metropolitan, inner, rural and regional) should be evenly distributed. CRAs have also designated a set of collection points from where they can only collect e-waste under the scheme. This is considered as the major drawback of the system. Sharing the collection points among the CRAs might ensure an adequate supply of e-waste for the recycling facilities. Furthermore, the scheme only considers TVs and computers which makes customer confused about what they can discard of. Sometimes, in the collection points, customers might come up with their old refrigerators but at that point, they have to pay for disposing of the item as the item does not fall under the category of the scheme. In Swiss system, SWISO and SENS share the same collection points and customers can dispose of any kind of WEEE items regardless of the brand. This creates a customer-friendly take-back system, as well as collection logistics difficulties are avoided to a great extent by sharing common collection points among the PROs.

V. Public Awareness about E-Waste, NTCRS and Willingness to Pay (WTP)

As part of the e-waste awareness assessment among residents in the city of Sydney, a pilot survey is currently going on. A questionnaire survey was developed in the online platform and respondent can provide their answer anonymously. So far, a total of 223 responses were received on several key indicators. In this study, three different responses are presented.

A. Knowledge about National NTCRS for Computer and Television Waste Recycling

Customers were asked, "Are you familiar with Australia's national television and computer recycling scheme (NTCRS)?". *It is found that 90% of the respondent didn't know about NTCRS.* This represents a quite limited understanding of the scheme among the customers. Liable parties have the responsibilities to educate customer regarding the scope and provision of the scheme and how they can access the service. During product purchase, this information can be given to the customers from the manufacturers and importers. In the case of Swiss system, customers are legally bound to return back their old and obsolete items to the collection points and their level of awareness are comparatively high [12].

Having a low level of awareness among customers may result in waste diversion from recycling to landfill and it also questions about the sustainability and effectiveness of the scheme. To develop a circular economy-based country customer must be engaged in the entire supply chain, both forward and reverse [3].

B. Locations of the Permanent Collection Points

In the second question, customers were asked either they know any collection points for e-waste or not. *Around 60% of the respondent said that they don't know where the location of a permanent collection point.* Local government should play a significant role in increasing awareness in this area. If customers do not know where they can dispose of their e-waste than eventually there is a high chance that e-waste is getting mixed with municipal solid waste (MSW) or stored at home for a long time. Storage is one of the critical issues in e-waste management [28]. Furthermore, in Australia, in some cases, customers need to go 100 km to find an e-waste collection point. In the Swiss system, recycling companies need to show that the distance between the collection points/retailers and recycling centers are 30 km or less for getting the contract. Reasonable access to the scheme for all customers is one of the major challenges that all the other stakeholders need to consider.

C. Willingness to Pay (WTP) for E-Waste Recycling

Customers were asked "What percentage of recycling costs would you accept paying for the following equipment?" for various kinds of product such as TV, monitor, laptop, tablet, mobile phone, printer, scanner and other IT equipment.

In response to the question, the majority of the respondent found that they are willing to pay for around 5% of the total cost of recycling for desktop and laptop PC. With this, it can be said that customers in Australia are willing to pay for the recycling, however, there is still a knowledge gap on who, how and when a product is recycled. Recycling fees (as ARF) is collected in Switzerland from the customers during the purchase of a new product and it is mentioned in the new product's purchase invoice. Psychologically, it is obvious that rather than taking money at the point of drop-off, it is much easier to collect the fee up-front. In such case, participation of the customers is also ensured. In Australia, Recycling companies working under CRAs collect a certain amount when customer is disposing their items in-person to a recycling facility. This is assumed as a counter-productive measure and

most likely customer is unwilling to return their items to recyclers directly. ARF mechanism in Switzerland avoids such inconvenience. Furthermore, for running an intergenerational system setting the fees is crucial and for that further assessment is essential in the area of e-waste amount estimation and future sales growth of EEE items.

VI. Conclusion

E-waste management is a complex task. Lesson learned from Switzerland will definitely improve Australian system particularly in the area of policy amendment by including new product range, distributing roles and responsibilities among stakeholders, and clarification of financial mechanism and control and auditing of the whole system. Public awareness is an important area that needs further investigation. Results from this study show that there is limited knowledge among the public regarding the NTCRS scheme and locations of the collection centers. However, the majority of the customers, on the other hand willing to pay for e-waste recycling. An integrated policy approach is needed that will ensure participation of all actors by securing finance and environmental sustainability of the e-waste management system in Australia.

Acknowledgment

The first author acknowledges the financial support from Macquarie University under the scholarship scheme "International Macquarie University Research Training Program Scholarship (iMQRTPS)" for conducting this research.

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