

Analysis of Drivers and Barriers for Personal Computer Re-use

A case study of secondary PCs in Taiwan

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Abstract

Personal computers (PC) have become an indispensable product in modern life. Along with the growing volume of computers, the environmental burden and impact at the end-of-life phase known as e-waste become significant. Considering the material-intensive nature of the production of computers, and the environmental burdens caused by landfills, incinerations and improper recycling activities, personal computer reuse can bring benefits from various aspects. Current policy puts more focus on e-waste management than reuse and producers are not participating in the secondary PC market, except for Microsoft.

This research tries to illustrate the framework of PC reuse activities and provides a background study for the enhancement of secondary PCs as a general counter-measure for growing e-waste problems. This research also examines literature and conducts a case study of stakeholder interviews to discover the drivers and barriers of PC reuse from the perspectives of three top international producers and policy makers and refurbishers in Taiwan. There are many factors to be considered before establishing a sustainable reverse supply chain for secondary PCs, such as reducing the safety risks and functional issues by building up computer reuse standards, seeking opportunities to lower the cost (user friendly total package of open OS, logistic partnerships, selections of reliable sources and optimal refurbishing locations and procedures), communication, incentives and stable channels for residents to resell or recycle their PCs in a timely manner.

To reflect global e-waste problems from Taiwanese practices, because of low recovery rate of old PC refurbishment (only 20 to 30% for four to six year old PCs obtained from various sources), this research suggests to establish the secondary PC standard as the first priority, request software and hardware producers to take aggressive actions, enlarge domestic market as much as possible and only allow the exporting of functional secondary PCs meeting standards to certain emerging markets.

Key words: PC re-use, e-waste, WEEE, secondary PC, computer and environmental impact

Executive Summary

PCs are an important sector with growing volume in the market. Owing to technological innovation, declining price and marketing stimulation, the rapid replacement and increasing popularity of computer use are happening in both developing and developed countries. Annual PC shipments have become over 300 million; ten times growth in 18 years. By 2014, the estimated shipment will be over 600 million. Worldwide PC penetration rate is 182 PCs per 1,000 persons. The US has the highest PC penetration rate – 928 PCs per 1000 persons. The environmental burdens of the fast growing PC industry are significant.

Manufacturing computers is a material-intensive process. One desktop computer consumes over 240 kilograms of fossil fuel – ten times the weight of the computer itself. Apart from the raw material extraction, according to a hybrid analogous study, the production of high-tech components in highly organized manufacturing such as semiconductors also requires high amounts of energy to purify starting materials and processing environments. The high energy intensity, coupled with the short lifespan of PC use in practice, leads to annual energy burden of ownership around 2,600 MJ per year – which is much higher than other home appliances. For example, it is 1.3 times that of a typical refrigerator. The life cycle energy consumption for a desktop PC in raw material extraction and production stage accounts for nearly 80%. At the stage of end-of-life disposal for used PCs, they are stored in the houses of consumers or treated by land fill, incinerated, or recycled by formal or informal sectors, or reused. Retired PCs per year were around 200 million from 2006 through 2010. Of the 200 million retired PCs worldwide, about 22% are in storage, 34% are disposed (recycled, landfilled or incinerated) and 44% are reused through different channels. The worldwide number of PCs being reused has increased from 55 million in 2004 to 86 million in 2007. Considering the short lifespan, the growing volume of computers, the material-intensive process of the production of computers, and the environmental burdens caused by landfills, incinerations and improper recycling activities, the reuse of personal computers can bring benefits from various aspects.

Through literature and reviews of main e-waste management policy schemes, it can be realised that existing policies focus mainly on e-waste management; policies particularly focusing on the reuse of electrical and electronic equipment (EEE) or computers are scarce. Moreover, the producers are normally not involved in the business of computer reuse and third party refurbishers are sometimes regarded as a cannibalization threat by original producers. Therefore, they gain limited information or have little incentive to improve their environmental impact or waste management by improving the reuse situation of computers. To a large extent, how the computers are refurbished and how the computer design can promote reuse rather than recycling are of no interest to producers.

This research seeks to explore the activities related to the reuse of personal computers, and identify the main drivers and barriers for computer reuse to improve the e-waste situation. By doing so, the research seeks to contribute to the development of policy instruments or business strategies that aim to enhance reuse that is environmentally and socially acceptable through a case study in Taiwan.

In order to meet the objective of this research, the information is gathered by a literature review, semi-structured interviews and in-depth interviews, either conducted in person or via telephone. The stakeholders included for interviews are four Taiwanese government bodies, 13 Taiwanese refurbishers, and three top hardware producers – HP in Taiwan and Europe, Acer in Taiwan and Dell in Europe and Sweden. This research focuses on the drivers and barriers associated with the activities operated by refurbishers of commercial sales and

donation and the asset recovery services offered by producers. Since government bodies have different responsibilities and producers run different operations, all their standpoints for drivers and barriers of secondary PCs are illustrated for the analysis and discussions. As for the in-depth interviews with refurbishers, due to higher similarity of refurbisher groups, the drivers and barriers perceived by refurbishers will be separated into high, middle and low levels. This analysis first uses the bar chart to identify the common drivers or barriers perceived by three stakeholder groups. The separated drivers and barriers will be recognized and discussed through the orders of government bodies, producers and refurbishers. The second part of the analysis is the comparative study to review the differences between the literature review and stakeholder surveys. The drivers and barriers not included in the literature review are summarised and presented.

PCs for reuse are a complex subject. The size of the market, the participants, the points of sources, the activities, the definitions, and the responsibilities are all diverse. PCs are reused through channels such as direct sale from the first owner to a buyer, internal reuse, donation and commercial intermediary transaction. An estimated annual volume of 86 million PCs are reused for commercial (sold through OEM, lesser, reseller or broker) and non-commercial (employee-purchased, end user to end user) resale. If not exported, these PCs are sold mostly to the small businesses or the private home segment. The secondary market is dominated by a handful of large brokers and dealers that buy large volumes of secondary PCs, mainly from large companies, and sell them either to one of the many local resellers specialized in marketing secondary PCs or to exporters. Gartner estimated that in 2008, 37 million secondary PCs were exported for reuse. The number is expected to increase to 69 million by 2012. In general, around 40 to 50% of retired PCs are reused domestically and 40 to 50% of reused PCs are exported.

Taiwan enforced its Waste Disposal Act in 1997 in which the government set up a public foundation – Recycling Management Foundation (RMF) – and producers are financially responsible for end of life disposal of their products. Most of the primary PCs from public and private institutional users are four to six year old and collected for recycling for end of life disposal. Before final treatment in recycling plants, the working components are sorted and reassembled to refurbish PCs for domestic market or export. This represents about 20 to 30% of total collected volumes. Primary PCs retired from large corporation companies in Taiwan are normally two to three years old. Retired PCs are refurbished by the medium-sized refurbisher (also called broker). The refurbishment rate can be up to 90%. Around 70% of refurbished PCs are exported.

Through interviews with stakeholders, it was identified that a driver for secondary PCs was that Taiwanese government bodies support PC reuse for resource conservation. Secondary PCs can aid to bridge digital divide and benefit low income families or disadvantaged groups. It also corresponded to national sustainable consumption policy for consumer protection in Taiwan. Commercial customers have more environmental awareness for safe IT disposal. Producers such as Dell, with a large share of commercial sales, provide asset recovery services on used PCs to business customers for selected countries and conserve natural resources. Refurbishers try to preserve resources and reuse components or systems when they are still workable. Raw material extraction and manufacturing stages account for a large percent of energy use in the lifecycle of a PC. Therefore, it is irresponsible to recycle still functional components. In general, PC or component reuse and resell give refurbishers higher profits than recycling.

As for barriers, five factors are commonly perceived by government bodies, producers and refurbishers for secondary PCs. They are small price differences between new and used PCs, rapid technological development, existing regulation, low collection rate (lack of available fleet machines, high volumes of used PCs with identical configurations, and high operational cost. The sixth barrier related to economies of scale is recognized by producers and refurbishers. The seventh barrier, concerning safety, functionality and quality is one of the key concerns of government bodies and producers. By looking at the legislation side, although the long history and promising achievement of waste recycling schemes and active practices in Taiwan, for PC products, existing governmental interaction – both Waste Disposal Act and national sustainable policy – lack central guidelines to promote product reuse. The Current Waste Disposal Act is also associated with high administration costs and low collection rates of mobile PCs from households. Regarding safety, functionality and quality of secondary PCs, international organizations urge for global standardisation of computer reuse requirement. Through interviews with stakeholders, it was found that the safety and functionality of secondary PCs do pose certain risks. A refurbished system without proper ElectroMagnetic Interference (EMI) and Electrostatic Discharge (ESD) solution may have interference on the communication and higher possibility for the systems to freeze up. The impacts of EMI issues on city users will be higher than rural area users. An airport area is a sensitive area as well. As for the issues of mobile PC reuse, the battery is the most critical item for safety. If refurbishers replace used laptop with other non-qualified battery sources, it might have the risk of burning or explosion. The worst case could lead to a house fire.

This research summarises recommendations to three stakeholders:

1. Government bodies: to conserve resources and promote sustainable development, government bodies can consider different policy instruments for secondary products/PCs, create regulatory instruments to define national standards for the safety and functional issues of secondary PCs, encourage the use of open OS and build codes for responsible refurbishing and recycling business, promote voluntary/informative instruments to educate consumers and raise consumer awareness to conserve natural resources by repair, reuse or resell their used products in a timely manner and consider purchasing qualified secondary products. For national sustainable policy in general, the concept for material reuse should be integrated. On the other hand, there are more and more product types for consumer electronics. Every brand product or each product model has its own specification for battery, charger and cable. EPA can work with industrial groups for common design of accessories items to improve the overall compatibility. Consumers can reuse the accessory items and producers can reduce their product environmental impacts by decreased material and packaging use. For the international level, to find optimal and sustainable scenarios of PC lifecycle, efforts should be made to resolve the environmental and social problems caused by rapid PC development and replacement. Microsoft and Intel are two main boosters for rapid technology changes and replacements. Considering the unique characteristic of computers, this research suggests EPR scheme to include processor and software supplier for responsible end of life treatment of PC lifecycle. Policy measures taken by countries with these important actors – most notably the United States – could play an important role. Furthermore, to discover the optimal approach for PC reuse and recycling, policy works can be separated into commercial and consumer primary users. Owing to the fact that large companies are main sources of exported used PC, the priority shall be given to international and national large companies follow Sustainability Reporting Guidelines through Global Reporting Initiative (GRI) for the interests of investors.

In addition to two waste criteria (EN 22 and EN 24), GRI index¹ can enhance the level to include new index for responsible and qualified resell, refurbishing and recycling practices.

2. Producers: It is important for both software and hardware producers to work together along with the efforts of refurbishers, international organizations and government bodies for establishing a global standard to eliminate critical concerns and deliver a total solution from refurbishment, service to safe disposal to customers in emerging market. Producers can also seek for win-win strategies to promote green products with longer warranty period, improve battery lifetime by designing user friendly setting, and consider selling the functions of the PCs instead of the PCs themselves. Last but not least, to protect branding image, it is not enough to claim “ban e-waste” export. The reality is that e-waste is not the same as other waste categories with very little residual value. Nor is it the same in terms of toxicity. The toxic trade will continue happening. Under booming social media trend, nothing is more serious than a report or an image which hurts brand image by discovering used PCs with companies’ logos which were dumped or improperly recycled by women or children under terrible conditions in developing countries. Software and hardware PC producers shall look for optimal solutions at international level to solve the toxic trade problems.

3. Refurbishers: governments have some resources for technical support to improve the remanufacturing and refurbishing operations. Refurbishers can apply for government projects and work together to establish national standards. While the national standard is established, the qualified refurbishers can build the network to improve the transactions of used components and PCs and share their experiences related to the upgrade of hardware and software. The recovery rate can be up to 65 to 90% for refurbishments of two to three year old PCs retired from commercial users. However, only around 20 to 40% yield rates have been achieved for refurbishments of PCs which are older and obtained from various sources. The quality, timing and quantity of returned PCs are important issues for reverse logistics. Refurbishers can consider building strategic business models and enlarging business scales. Similarly, to a second-hand market approach of Bestbuy², a specialty retailer of consumer electronics in the United States and Canada, refurbishers can consider building a partnership with some retail chain stores to sell and collect used computers from consumers and have proper communications or sales package to private consumers in advance for efficient collection and refurbishment. For efficient collection, in Taiwan, there is a successful model for dry cell battery recycling. The second biggest convenience store, FamilyMart, runs the program to encourage private consumers to properly recycle and exchange used batteries, mobile phones and computers for boiled eggs, hotdogs and cold drinks³. In total 2350 stores run this program and have collected 100 tones of batteries in five months.

This research further suggests future research: 1) some demand and supply site studies such as the surveys of primary users, brokers and secondary users, the internet auction, exports of non-working PC, leasing programs and commercial returns; 2) geographies – the fastest-growing regions in demand sites are the Middle East and Africa (MEA) and in Asia/Pacific. The countries from supply sites are the United States and Western Europe countries; 3) full life cycle assessment of mobile PC including netbook and tablet PC: without full life cycle assessment for computer to include recent figures for new material toxicity, raw material extraction, manufacturing, usage and final disposal (dumping and landfills, recycling-low and

¹ <http://www.globalreporting.org/GRIReports/GRIReportsList/>

² http://barryjudge.com/secondary-markets-a-new-growth-opportunity-for-best-buy?sms_ss=facebook

³ http://www.family.com.tw/enterprise/news_in.aspx?ID=140

high standard, and open burning), it is still hard to determine if it is better to recycle or reuse a used PC.

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1 Introduction

1.1 Background Information

A personal computer (PC) is any general-purpose computer useful for individuals in terms of its size, capabilities, and original sales price with intention to be operated directly by an end user, instead of intervening a computer operator. A PC can be a desktop computer, a mobile computer, tablet PC or a handheld PC. While early PC owners usually needed to write their own programs and set the command to run the PC, today's users have the access directly to those commercial and non-commercial software. Since the 1980s, Microsoft and Intel have dominated most of PC market with the Wintel platform (Vasquez 2008).

PCs are an important sector with growing volume in the market. According to shipment figures of Gartner, a global independent information technology research and advisory firm, global PCs installed bases had been more than 1.25 billion by the end of 2009. Worldwide PC penetration rate is 182 PCs per 1,000 persons and shipments reached a total of 306 million units in 2009; an increase of 5.2 per cent over the previous year and ten times higher than the year 1992 (Gartner 2010a). In 2010, PC shipments are estimated to reach 366 million units with 20 percent growth compared to 2009. Mobile PC shipment had exceeded desktop based PC in 2009 with 55 percent share. Gartner's latest forecast also indicates mobile PC shipments will account for 70 percent of total PC shipment by 2012 (Gartner 2010b).

The environmental burdens of the fast growing PC industry are significant. Manufacturing computers is a material-intensive process. One desktop computer consumes over 240 kilograms of fossil fuel – ten times the weight of the computer itself. Compared to an automobile or a refrigerator, measuring the amount of fossil fuels used in comparison to their weights, the pound for pound requirements to make one computer is very high. There are also considerable quantities of chemicals (22kg) and water (1500kg) used (Kuehr & Williams 2003). Apart from the raw material extraction, according to a hybrid study analogous (Hatanaka & Williams 2005), the production of high-tech components in highly organized manufacturing such as semiconductors also requires high amount of energy to purify starting materials and processing environments. The high energy intensity, coupled with the short lifespan of PC used in practice, leads to an annual energy burden of around 2,600 MJ per year which is much higher than other home appliance. It is 1.3 times that of a typical refrigerator. The life cycle energy consumption for a desktop PC in raw material extraction and production stage accounts for nearly 80%. Though there is no similar analysis done for mobile PCs yet, pure process studies make no large difference between a desktop and a mobile PC. It can also be explained by the fact that a relatively small share of bulk materials accounts for the total energy burden, and the additional energy required is used to achieve a more compact form of mobile PC (Hatanaka & Williams 2005).

Owing to technological innovation, declining prices, and marketing stimulation, the rapid replacement and increasing popularity of computer use are happening in both developing and developed countries. The significant volume of electrical and electronic equipment waste (“e-waste”) – every year is around 20 to 50 million tons generated worldwide – puts enormous pressure on human health and the environment (UNEP 2005). This e-waste is either stored in the houses of consumers or treated by land filled, incinerated, or recycled by formal or informal sectors, or re-used. From 2006 through 2010, Gartner estimated consumers and businesses will replace more than 925 million PCs worldwide (Lapierre & O'Brien 2006). In 2008, over 180 million PCs were replaced—approximately 16 percent of the existing installed

base and 50 percent of the yearly shipment quantities. A fifth of these retired PCs, or some 35 million PCs were just dumped into landfills without the consideration of their toxic contents. The disposition of retired PCs is a serious issue for PC vendors, governments and environmental groups. It will become an even more pressing issue, especially in developing countries, as the number of retired PCs grows with the continuing expansion of the PC installed base (Escherich&Smulders 2008).

A recent report released by UNEP on September 2009 shows that the e-waste by 2020 from old computers will increase 200 to 400% from 2007 levels in South Africa and China and up to 500% in India (UNEP&StEP 2009). US Environmental Protection Agency estimates that there are 30 million desktop and 12 million mobile PCs discarded in 2007. It is equivalent to over 112,000 computers discarded per day. E-waste is a fast-growing category in municipal waste. In US, compared to the annual increase of the total volume of municipal waste which is 1.2%, e-waste growth rate was up to 8.6% in 2006. In the EU, the volume of e-waste is estimated to increase by 3 to 5 per cent a year (ETC 2009).

To tackle e-waste problems, several regions/countries established legal frameworks to implement extended producer responsibility schemes to mandate producers to take-back end of life products and prohibit e-waste entering landfills or incinerations. Furthermore, in order to ensure the sound and safe recycling process in place, both EU and USA run the projects to promote standard and qualified operations⁴⁵. Because many different toxic components contained in electronic waste, including computers, are considered hazardous by the Basel Convention (of 1989) Technical Working Group (TWG), in 1994, parties to the Basel Convention, which is over 60 countries, agreed to immediately prohibit the export of hazardous wastes destined for final disposal in non-OECD countries. However, under the agreement of exporting and importing countries, there are still used EE products exported for the purpose of recycling or reuse among OECD and non-OECD countries (UNEP 2002). According to existing worldwide legislation, reuse can be part of the practices but not really well defined or explored.

The term “re-use” has several definitions in international laws, policies, norms and practices. There is no globally agreed definition, and this causes a lot of confusion among academia, government, business and consumers. Eventually, it hinders an efficient re-use market. The StEP Initiative, an initiative of various UN organizations with the overall aim to solve the e-waste problem, defines “Re-use” as following (StEP 2009),

“Re-use of electrical and electronic equipment or its components is to continue the use of it (for the same purpose for which it was conceived) beyond the point at which its specifications fail to meet the requirements of the current owner and the owner has ceased use of the product.”

In addition, Gartner defined a secondary PC as follows,

“A PC that has been used for more than three months by its primary/initial user and then made available to another user for secondary use is a secondary-market PC. This category excludes PCs which have been returned

⁴United States Environmental Protection Agency Responsible Recycling (R2) Practices for Use in Accredited Certification Programs <http://www.epa.gov/osw/conservation/materials/recycling/r2practices.htm>

⁵ WEEELABEX, approved by the Life committee, an EU body composed of representatives of the member states and of the European Commission, aimed at achieving European standards with respect to collection, treatment, recovery and recycling of waste electrical and electronic equipment (WEEE) and monitoring the processing companies.

<http://www.weee-forum.org/index.php?section=weeelabex&page=weeelabex&weeeforum=bf2880f66306ea39a3e32fdec4720916>

to the original seller because of faults or buyer's remorse.” (Escherich&Smulders 2005)

Above two definitions will be used as working definitions for this research.

1.2 Problem Description

PC for reuse is a complex subject. The size of the market, the participants, the points of sources, the activities, the definitions, and the responsibilities are diverse. The worldwide number of PCs being reused has increased from 55 million in 2004 to 86 million in 2007. Approximately 197 million PCs were retired in 2007, but although worldwide demand is still larger than supply, fewer than half found their way into reuse. The market for used PCs varies by region, especially as a result of the legal and regulatory environment, but currently the fastest-growing regions in terms of demand are the Middle East and Africa (MEA) and in Asia/Pacific. Though it is an opportunistic market, it is also extremely fragmented with tens of thousands of players involved (Escherich&Smulders 2008)

Through the literatures and reviews of main e-waste management policy schemes, it can be realised that existing policies focusing mainly on the e-waste management, policies particularly focusing on the re-use of electrical and electronic equipment (EEE) or computer is scarce (Kuehr &Williams 2003). Moreover, the producers are normally not involved in the business of computer re-use and third party refurbishers are sometimes regarded as a cannibalization threat by original producers (Blass & Geyer 2009). Therefore, they gain limited information or have little incentive to improve their environmental impact or waste management by improving the re-use situation of computers. To a certain extent, how the computers are refurbished and how the computer design can promote re-use rather than recycling are of no interest to producers.

The market situation as well as the drivers and barriers for computer re-use need to be explored in order to develop the policy or business strategy for re-use/recycling systems which are environmentally safe, encourage re-use of computers, and provide jobs. Thus, the problem description of this research is:

While recycling and re-use can be found in many e-waste management policy instruments, little attention is paid to the re-use of EEE or the differentiation of re-use schemes from recycling. Neither policy makers nor producers have strong engagement with or interest in large scale of PC re-use.

1.3 Objectives and Research Questions

Considering the short lifespan, the growing volume of computers, the material-intensive process of the production of computers, and the environmental burdens caused by landfills, incinerations and improper recycling activities, the reuse of personal computer can bring benefits from various aspects.

This research seeks to explore the activities related to the reuse of personal computers, and identify the main drivers and barriers for computer re-use to enhance e-waste situation. By doing so, the research seeks to contribute to development of policy instruments or business strategies that enhance reuse that are environmentally and socially acceptable. In achieving the objective, taking the situation in Taiwan as a case, the research answers the following research questions.

1. What are the drivers and barriers for computer re-use that are identified in existing literatures?
2. What are the current state of computer re-use by different actors and the characteristics of the re-use process?
3. What are the views of policy makers, producers, and refurbishers regarding computer re-use?
4. How are the views of the actors compared to the drivers and barriers identified in the literature?
5. Given the barriers and drivers, what might be the possibilities to enhance the re-use market and smoothen the re-use activities?

1.4 Scope and Limitations

1.4.1 Scope

In terms of computer re-use and recycling, there are several works of literature in favour of re-use, but also many which prefer the recycling option. Ahluwalia and Nema (2007) in the article “A life cycle based multi-objective optimization model for the management of computer waste” developed a schematic diagram showing different factors which will influence the waste management hierarchy and re-use at the top with the maximum width, indicating maximum preference to management option. Kuehr and Williams (2003) stated that the lifespan of computers shall be extended and prioritised in their environmental managements. One important and practical method is to encourage markets for used PCs. Moreover, Hsiao et. al (2006) examines three disposal options in Taiwan - re-use via the second hand market, recycling and incineration or landfill through cost benefit and lifecycle impact analysis. The results show the primary focus shall be on the re-use of computers or components. However, OECD (2001) points out that re-use of PCs are still in doubt to gain a positive outcome (the environmental benefits are difficult to justify while the use of second hand computers is not likely to displace the purchase of new systems). A study of the economics of cell phone re-use and recycling by Blass and Geyer (2009) refer to the fact that in the cell phone sector, displacement brings the biggest environment benefit through the re-use. Most experts believe that displacement rates of secondary metals could be very high, while those of cell phone re-use are probably low. This could mean the environmental benefits of cell phone recycling actually outweigh re-use. Unfortunately, none of existing studies provides a full Life-Cycle-Analysis (LCA) of computers, let alone a wider assessment of sustainability for the impacts of computers (Des Autels & Berthon 2009). Despite these conflicting views on the superiority of re-use, individual volume studies of re-use are much less than recycling. Thus, this research focuses on the re-use option and specifies the limitation and future works for further studies.

Based on the general term of re-use according to the definition of StEP initiative and Gartner Inc. provided in section 1.1 and the activities associated with secondary PCs, studied in this research is further narrowed down. Since various participants get involved in secondary PC markets, this research chooses to evaluate the standpoints of main global PC hardware producers, governmental bodies and refurbishers of Taiwan.

Taiwanese manufacturers dominated around 80% of the mobile PC global market and accounted for one third of the top six PC hardware companies. Taiwan enforced its Waste

Disposal Act in 1997 and as a result the government set up a public foundation - Recycling Management Foundation (RMF) and producers became financially responsible for the end of life disposal of their products. Qualified recyclers get the subsidy allocated from RMF based on the reported amounts of recycled electrical or electronic equipments. In the mean time, the Environmental Protection Agency (EPA) of Taiwan initiated the program of used PC donations for the promotion of resource re-use and digital divide reduction in 2006. It is a four year project plan for bridging digital divide of Executive Yuan since 2006 to 2009. The existence of the manufacturers and policy initiatives provide a good empirical base to study.

1.4.2 Limitations

Given the complexity and fragment of secondary PC market, it is hard to obtain clear figures about secondary PC market size and the amount of participants through interviews. Moreover, there is no recent data on secondary PC market of Taiwan in literature or researches. In a master thesis conducted in 2001 about market research of waste computer recycling in Taiwan, it is estimated that 14% of discarded IT products from public or private sectors and households flew to secondary market and 8% were exported (Chang 2001).

Owing to the active IT business in Taiwan, there are many skillful persons handling PC repair, refurbishing or sales business. There are significant amounts of refurbishing businesses that are run by families, with two or three employees. Both informal and formal sectors run refurbishing business or new or secondary PC sales. Owing to the sensitive and fragility of operations, it is hard to identify the interviewed refurbishers as belonging to the formal or informal sector. Moreover, due to the lack of large refurbishers in Taiwan, more studies about their practices will be required for further studies. In regards to the interviews with producers, Hewlett-Packard (HP), Dell, Acer, and Lenovo offices in Taiwan were approached. However, the author cannot get responses from Dell and Lenovo Taiwan. Dell Europe and Sweden was interviewed instead. As for Lenovo, Lenovo in United States replied but it was unable to allocate resources for adequate responses. In the mean time, because of business confidentialities, Dell is not able to provide some general figures about take-back status for commercial customers in Europe as regard to the proportion of recycling through Dell partners, asset recovery service through Dell partners and brokers through non-Dell channels.

There are gaps in the comprehensive life cycle analyses (LCA) for computer products, caused by lack of access to raw material data for new technology, different scenarios of energy use at usage stages and illegal/informal recycling during disposal stages. It is hard to determine whether re-use is a better option than recycling in terms of environmental aspect as listed in section of 1.4.1 Scope. Since displacement brings the most environment benefits through re-use (but new generation PC perform better in power consumption), further LCA researches will be required to consider both displacement scenarios (resale may result in displacement rather than donation) and the difference of power consumption in old and new PCs for a justified approach. However, this area is not in the scope of this paper. They can be further examined in future works.

1.5 Thesis Structure

The research structure is as follows.

Chapter 2 starts from the description of global PC market and main producers. It then continues by an illustration of forward and reverse manufacturing for a PC to understand how PCs can be manufactured and remanufactured. Later sections disclose secondary PC flow,

associated activities and identifying drivers and barriers for computer re-use through literature review.

Chapter 3 describes the scope and limitations of the geography, participants and the associated activities. To explain how this research is done, the subsequent methodology section gives details about the literature review, data collection and analysis method and the analytical framework provides an overview for research areas.

Chapter 4 describes the secondary PC situation in Taiwan by synthesising the findings obtained from interviews of key stakeholders.

Chapter 5 portrays the drivers and barriers from the perspectives of stakeholders about secondary PCs in Taiwan. It then follows by a comparative analysis of views among stakeholders and the discussions of common and individual drivers and barriers in Chapter 6.

Chapter 7 summarizes the main findings, provides recommendations and concluding marks. The final section suggests future works related to the issues of computer re-use.

2 An Overview for Personal Computer Production

2.1 The Global Market

Global PC production grew by 5% annual and reached 306 million units in 2009. Desktop PC comprises of 45% of this production, mobile PC, 45% and mini notebook PC, 10%. Forecast of PC shipment made by Gartner in 2014 will be up to 600 million units and achieve almost 100% growth rate compared to 2009(Gartner 2010b). The annual growth rate is around 14.5% from 2009 to 2014. On the other hand, the proportion of desktop PC will be decreased to 25%, mobile PC will increase to 63% and mini notebook PC will be around 12%. In 2009, Hewlett-Packard (HP) leads No.1 position with the market share of 19.3%, followed by Acer with 13.0% market share and Dell is ranked as No. 3 with 12.2% market share (Gartner 2010a). Table 2.1 provides the market share figures of hardware PC producers.

Table 2-1 Hardware PC Producers Worldwide Market Share

| Producers | 2009 Market Share |
|----------------------|-------------------|
| Hewlett-Packard (HP) | 19.3% |
| Acer | 13.0% |
| Dell | 12.2% |
| Lenovo | 8.1% |
| Toshiba | 5.1% |
| ASUSTeK | 4.3% |
| Apple | 3.6% |
| Samsung Electronics | 2.2% |
| Sony | 2.0% |
| Fujitsu | 1.8% |
| Others | 28.5% |
| Total | 100.0% |

Source: Gartner 2010a

The number of PCs installed worldwide⁶ has surpassed 1 billions units in 2009. Gartner analysts estimated it will surpass 2 billion units by early 2014. Table 2.2, the installed base of PCs concentrated highly in mature markets such as USA, Canada, Western Europe and Japan. However, it also suggests that the emerging market will have a rapidly raising PC penetration and continues to drive strong PC growth (Gartner 2009).

The global PC installed base is spinning as PC users replace their used machines with new ones. Some retired PCs are back into the installed base of the second owners through various channels, some are broken up and recycled either legally or illegally, and others are dumped into landfills.

⁶ Gartner defines the installed base of PCs as the estimated number of PCs in use as opposed to the number shipped over a given a period, which is reported in Gartner's PC forecast and market share reports.

Table 2-2 Worldwide: PC Installed Base and Per Capita Penetration by Region, 2009 and 2014

| | Year | 2009 | Year | 2014 |
|------------------------|-------------------------------|----------------------|-------------------------------|----------------------|
| | PC Installed Base (Thousands) | PCs/1,000 Population | PC Installed Base (Thousands) | PCs/1,000 Population |
| Worldwide | 1,241,441 | 182 | 1,969,473 | 274 |
| United States | 289,308 | 928 | 439,278 | 1,347 |
| Canada | 30,502 | 912 | 45,213 | 1,295 |
| Latin America | 111,012 | 189 | 212,806 | 343 |
| Western Europe | 255,012 | 632 | 358,914 | 879 |
| Eastern Europe | 89,482 | 223 | 113,914 | 286 |
| Middle East and Africa | 55,672 | 44 | 101,859 | 74 |
| Japan | 78,866 | 617 | 89,486 | 705 |
| Asia/Pacific | 331,588 | 90 | 608,004 | 156 |

Source: Gartner 2009

2.2 The Forward and Reverse Manufacturing of Computer

Figure 2.1 illustrates the stages of forward manufacturing on the left side and reverse manufacturing on the right side. The activities of forward manufacturing include material manufacturing, component manufacturing, product assembly, and distribution and sale. The reverse manufacturing comprises of acquisition, assessment, disassembly, and reprocessing. Remanufacturing, refurbishment, recovery and recycling are other terms to describe reverse manufacturing practice. Two ancillary stages drawn in the middle of diagram intend to return refurbished/reconditioned products back to use by primary user or secondary user after the testing and repair, which may operate along with forward-chain warranty and service programs, and redistribution and resale, which may be integrated with forward distribution and sale (Beckman et al. 2003).

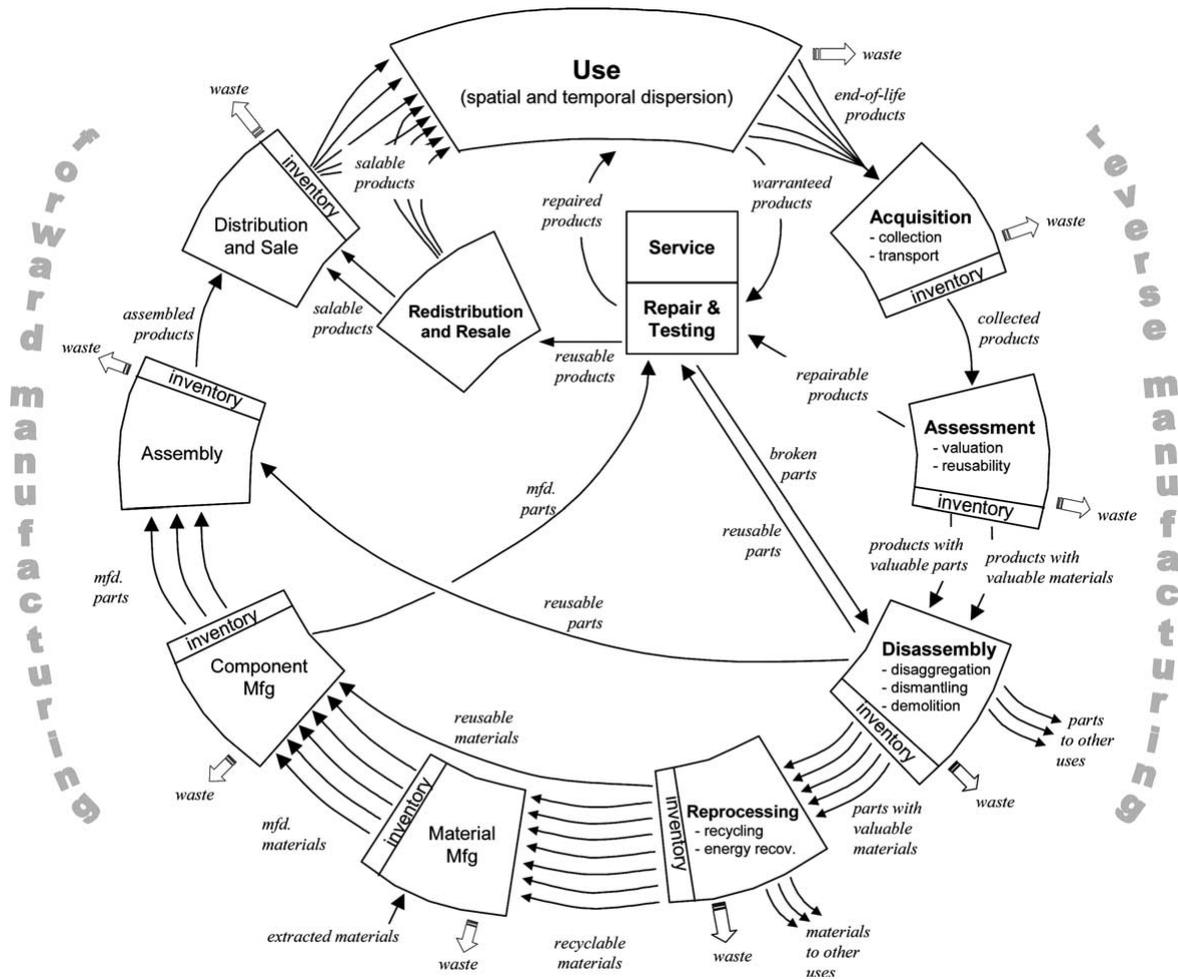


Figure 2-1 Forward and reverse manufacturing

Adopted from Beckman et al. 2003

2.3 The Point of Sources for Computer Reuse

The points of source for computer reuse are diverse. They can be off-leased products or asset recovery systems from business sectors, the customers' unwanted machines for resale, donation, recycle or disposal, or the customers' returned products for cash-back. In some countries, customer can have 7 days to 90 days free trial period. Some refurbished products offered by PC producers are collected from customer returns (open box and unused or used PC), cancelled orders, the damages on cosmetic flaws or broken parts during transportation, the overstocks, the demonstration for refurbishment.

Figure 2.2 shows the secondary PC market flow for a professional desktop. In most cases the model assumes that there are a maximum of three intermediary stages within a country. This is based on market participant feedback regarding the relative value of a PC in comparison to the transportation and handling cost (Escherich&Smulders 2005).

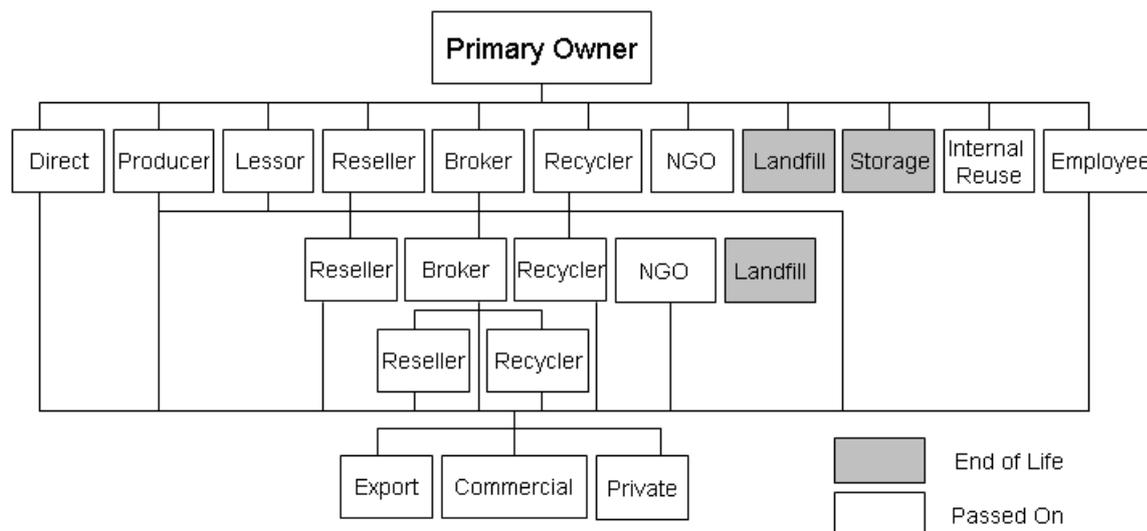


Figure 2-2 Secondary PC market flow for a professional desktop

Source: Escherich&Smulders 2005

Off Leasing: In theory, a lessee returns a used computer at the end of lease term to his/her lesser (producers or their channel partners). The lessee does not own the equipment but only has the right to use the equipment for a certain period of time. Therefore, he/she has no legal responsibility for the disposal. When disposing IT equipment incurs certain costs and risks, business may regard leasing as an attractive alternative to minimise the costs and risks. However, this is only partly true. By definition, a lease is contractual arrangement that the asset owner (lessor) grants the use of his or her property to the other party (the lessee) under certain conditions and within the specified period of time. However, not all leases are true leases. According to accounting rules established by the Financial Accounting Standards Board (FASB)⁷, equipment leases are classified as operating lease or capital lease.

- An operating lease (known as a "true lease"): a funding mechanism whereby you pay for the use of the equipment, not the ownership.
- A capital lease (known as a "finance lease"): a funding mechanism whereby the ownership of the asset usually transfers to the lessee at the end of the lease term.

Capital lease will be just another type of loan or financing for the purchase of the equipment. One criterion for a standard operating lease is that the present value of the stream of lease payments is less than 90% of the original equipment cost. This means that the lesser must take a residual value position of 10% or more. In most cases, the lesser only offers operating lease treatment for 36 months. Therefore, if the business plans to use the equipment beyond this time frame, then it is unlikely that it would be able to have an operating lease (O'Brien 006).

Asset Recovery: Producers such as HP and Dell⁸ or their channel partners offer asset recovery services for either small medium business customers or large corporate customers in

⁷ The designated private sector organization in the US <http://www.fasb.org/home>

⁸ Dell Services Asset Recovery

selected countries. Business customers can purchase this service for secure hard disk data destruction and safe IT equipment disposal. The asset recovery services vary from supplier to supplier. They can be the options for donation, trade-in, cash back, or recycling. The service providers collect the used equipment for refurbishment, components reuse or recycling.

Refurbishment for Commercial Returns: there are many large scale PC refurbishing businesses operating in U.S. to deal with commercial returns by households. The process of product returns is becoming a major concern for many manufacturers. The total value of products returned by households in the U.S. is tremendous - estimated up to \$100 billion annually. The typical situation is that customers can return the products for any reason within up to 90 days of sales and manufacturers must credit the retailer (or reseller) and then decide how to dispose of the product in most profitable way. PC producers may cooperate with refurbishing companies to refurbish or resell those commercial return products (Blackburn et.al 2004).

Donations: there are a number of organizations around the world to facilitate the donations of used IT equipment. In general, the market value of the machine and the cost of warehousing and transportation are tax-deductable. For instance, the Cristina Foundation in the United States concentrates on donation and training for disabled and poor persons. In North America, the Computers for Schools network establish the links between donors and local schools. It is estimated by Wayne Tosh of Computer for Schools that 400,000 used computers have been placed in Canadian schools. Also some other organizations are dedicated in the donations to developing countries, such as the African Computer Literacy Project (Ghana) and the African Regional Counsel for Computing (Kenya) (Kuehr&Williams 2003). For business sectors in US, donors are allowed to deduct the un-depreciated value of the computer. As regards private sectors, they can deduct the current market value of computers (CC 2010).

Secondary Market for Consumers: Consumers go through resellers to resell the PC. Resellers are agents that deal with the re-use of PCs and employ the processes of evaluation of main functions and specifications, quotation, functional test, refurbishing, software installation and/or provide warranties (from zero to one year). In a transitional shop, normally run by a reseller, customers can check products before purchasing. In the United States, the largest PC reseller chain is the Computer Renaissance franchise, which owns 110 stores in North America. Owing to the internet boom, the reselling of used PCs is very active; a large amount of small and medium-sized enterprises are involved in this business (Kuehr & Williams 2003).

Brokers are intermediaries who only provide information to potential secondary users about existing machines. Classified print advertising is the traditional communication tool in secondary markets. It facilitates the link between local buyers and sellers and reduces the transportation cost. Internet auctions also expand the market of buyers and sellers and demonstrate a popular and successful model (Kuehr & Williams 2003). In the U.S., eBay (the world-known auction and shopping website) is largest online auctioneer, expediting the trade of IT equipment. In 2001, the proposition of \$2 billion IT equipment sales value is 46% secondary equipment, 14% refurbished, and 40% new (Keafe 2002).

In January of 2005, eBay launched the PC Re-use and Recycling Initiative named “Rethink” to gather together the leading technology companies, government agencies, environmental groups and million of eBay users to face with the e-waste problem. Intel Corporation acts as its primary ally. There are other joint efforts by industry leaders Acer, Apple, HP, Lenovo and Ingram Micro with the U.S. Environmental Protection Agency, the non-profit organization (NGO) Silicon Valley Toxics Coalition, United Parcel Service (UPS) and the U.S. Postal Service, among other participants (eBay 2005).

Working computers can be sold or donated through the Rethink Initiative site. There are selling tools to help users, including a secure data destruction utility, helpers for automatic identification of system components, and information about shipping with protective shipping kits. The site also provides access to a catalogue of third-party resellers who can pick up one or more items and then sell them on behalf of PC owners. Another directory helps businesses outsource the disposition process to a local specialist in charge of asset recovery. PC owners can also choose to donate their working computers to the National Cristina Foundation (eBay 2009).

However, in China and India, the informal collectors and refurbishers/recyclers dominate the secondary PC market. Most home appliances and electronic equipment are sold to street collectors or the second-hand market. The informal collector is the primary actor to judge how the used PC can be separated - either components or entire item for re-use. Collectors pay the price to residents based on the revenue from selling some obsolete products directly for re-use, the components for re-use, or rest for the recovery. The ages, conditions or the value content of sold appliances are actually not taken into accounts. This fact complicates the structuring of a formalized collection system. In order to obtain e-waste, the return incentives set by formal system must compete with the price paid by informal sector (Bader et al. 2005).

Refurbishing/Remanufacturing by OEM: In the business operations of IBM, to reduce product waste at EOL, a leasing and remanufacturing program, remanufacturing operations, and used-parts recovery are operated. Product take-back service is align with a global array of product end-of-life management (PELM) centres which process tens of thousands of metric tons of EOL products. The returns can be categories into products used internally at IBM, end of lease returns, returns owned by business customers or from private or small customers. IBM has its strength in the capabilities of product recoveries contributed by the early business model in leasing equipment. Leasing offers the incentives for recovery and refurbishing or upgrading of equipment that the values can be retained for extended revenues. After the used PC is cleaned, repaired, tested and upgraded as needed, it is resold by IBM or through broker partners (Brinkley & Höhn 2003).

2.4 Secondary PC Market

Since the significant portion of commercial returns in the United States, Gartner defined that a secondary PC is a PC that has been used for more than three months by its primary user and then made available to another user for secondary use. Secondary PC market is a highly fragment. To understand the structure and the nature, it is important to understand the market participants and activities. Participants may carry out multiple functions. Take reseller as an example, they may provide asset management, refurbishment and resale services (Escherich&Smulders 2005). For the role of brokers, this research recognized that some brokers in Taiwan and in Europe⁹ also run asset management and refurbishment services for

⁹ The evolution of secondary market by an IBM broker since the Mid-80s

<http://www.powersourceonline.com/magazine/2009/05/broker-marketplace-has-evolved>

used PCs.

In 2005, Gartner developed a methodology to assess worldwide secondary PC market size. To evaluate this market, they do a repeat survey including the interviews with key players in each region/channel to ascertain the characteristics, continuing studies of user wants and needs, as well as the available industry information (Escherich&Smulders 2005). For the PC retired in 2007, it is estimated that out of 197 million units of PC, with the proportion of 75% desktop and 25% notebook PCs, about 22% of replacement PC were in storage, 34% were disposed of (either recycled, land filled or incinerated), and 44% were reused through different channels, such as direct sale from owner to a buyer, internal reuse, donation and commercial intermediary transaction (Escherich&Smulders 2008). Worldwide demand for secondary PCs is still larger than supply especially for notebook.

Approximately one in three PCs dedicated for reuse is exported from mature to emerging markets. Export tariffs and high transportation costs are still key factors restricting export volume. The survey done by Gartner identified North America, Western Europe, Japan and Australia to be the largest exporters of secondary PCs. They are on the supply side. On the demand side, the imported countries are in Latin America, Central and Eastern Europe, Middle East and Asia Pacific. Retired PC may be sent to landfills (less percentage for countries in Western Europe and Japan due to legal requirement), recycling, storage or re-arrangement for commercial or non-commercial sale. Around 23% retired PC stored in warehouses, cupboards or houses in those mature markets and less than 15% in emerging markets since every PC has a value to someone and the booming market and exchange for cash are much more popular in those markets. Overall, 64% of secondary PCs are being reused as opposed to 38% in supply countries (Escherich&Smulders 2008). Table 2.3 shows the breakdown of those retired PC in mature and emerging markets.

Table 2-3 Retired PC Disposition in Mature Markets and Emerging Markets 2007

| Categories | Donate | Repurpose in Home or Business | Non-commercial Resale | Commercial Resale | Store | Dispose |
|-----------------|--------|-------------------------------|-----------------------|-------------------|-------|---------|
| Mature Market | 3% | 8% | 8% | 19% | 23% | 39% |
| Emerging Market | 0.4% | 20.4% | 10.6% | 32.7% | 14.6% | 21.3% |

Source: Escherich&Smulders 2008

An estimated annual volume of 87 million PCs were reused for commercial (sold through OEM, lesser, reseller or broker) and non-commercial (employee-purchased, end user to end user) resale in 2007. If not exported, most of used PCs are sold to the small businesses or the home segment. The approximate resale value of a typical 3-year-old average-configuration DT PC is about \$50 to \$90 (excluding screen), and \$150 to \$250 for a mobile PC. The secondary market is dominated by a handful of large brokers and dealers that buy large volumes of used PC from large companies, and sell them either to local resellers specializing in marketing secondary PCs or to exporters. Gartner estimates that in 2008, 37 million secondary PCs were exported for reuse. The number will increase to 69 million by 2012 (Escherich&Smulders 2009).

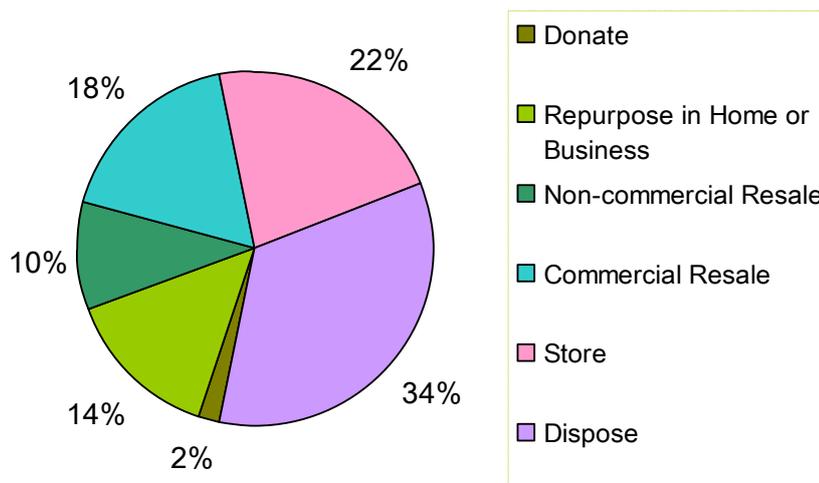


Figure 2-3 Retired PC disposition worldwide 2007

Source: Escherich&Smulders 2008

2.5 Identification of Drivers and Barriers for Reuse

Through the literature review, the author identified several drivers and barriers which potentially make significant influences on computer reuse and secondary PC market.

2.5.1 Identifying Drivers

In the book entitled *Computers and the Environment: Understanding and managing their impacts* wrote by Kuehr, Ruediger and Eric Williams. It mentioned the computer reuse can bring environmental benefits by reducing raw material extraction and manufacturing stage, and social and economic benefits for more job opportunities in developing countries.

Gartner analyzes the drivers for secondary PC markets are overall worldwide technology demand; PC installed base opportunity: growing installed base of primary PCs ; business opportunity: refurbished PC have equal or better margins than new PCs and lower capital outlay equivalent to higher return on investment and legislation: Producers are forced to take back PCs in some regions(Escherich&Smulders 2008).

In the report of Australian E-Waste Think Tank, an event organized by the Canberra Environment and Sustainability Resource Center (CESRC), Australian National University, and ACT Commissioner for Sustainability and the Environment in May 2008 and gathered the stakeholders from public and private sectors, three main drivers to the sustainable use, reuse and recycling of electrical or electronic equipment are as follows, clear guidance regarding efficient use of resources, consumer awareness, and sizeable reuse market ().

For further understanding of the potential interests to policy makers and producers, this research conduct more literatures related to the area of computer re-use and e-waste situations, additional drivers identified are resource conservation (Allenby et al. 2008), bridging digital divide (ITU 2003), and benefiting to low income families (Allenby et al. 2008).

Some drivers above such as overall worldwide technology demand and PC installed base opportunity: growing installed base of primary PCs are mainly for global situation. Other drivers more related to demand site or user side, they are not included in the survey primarily because the users are not in the survey group for this research. To conduct the interviews with Taiwanese government bodies, international producers and refurbishers in Taiwan, this research considered the particular features of stakeholders, domestic market and policy framework in Taiwan and concluded following drivers for this research.

1. Resource Conservation
2. Bridge Digital Divide
3. Benefits to Low Income Families
4. Profitability

2.5.2 Identifying Barriers

In the book entitled “Computers and the Environment: Understanding and managing their impacts” written by Kuehr, Ruediger and Eric Williams, it listed the obstacles to the re-use of PCs were the issues of software licensing, data security, and user awareness/demand and supply issues.

Moreover, Gartner analyzed the barriers for secondary PC markets are 1) Economics: rising transportation costs, environmental legislation, falling average selling prices of new PCs and software license costs, 2) Security: data security concerns encourage recycling rather than reuse, 3) Legislation and Tariffs: import tariffs and legislation impedes new-player entry. 4) Lack of available fleet machines (high volumes of used PCs with identical configurations), 5) Lack of consumer awareness and remote geographic areas are still hard to serve

The report of Australian E-Waste Think Tank event illustrated that key barriers were 1) Lack of legislation, 2) Lack of Research and Development, 3) High transportation cost, 4) Lack of consumer awareness, 5) Focus on recycling, 6) Fragmented industry and groupings, 7) Lack of economies of scale

From semi-constructed interviews with three Taiwanese professors in the field of e-waste study and researchers in environmental information centre, this research summarises more barriers as follows 1) the cost and availability of spare parts, 2) threats to producers and recyclers, 3) the lifetime of components and reliability of used computer; 4) Unreliable sources; 5) Safety and quality concern after refurbishment. They are discussed during stakeholder interviews.

One additional barrier highlighted by the authors of combating adverse selection in secondary PC markets is the rapid technological development (Hickey & Patrick 2008).

Considering the characteristics of stakeholders, for barriers more related to demand site or user side such as data security and consumer awareness, they are not included in the survey. For similar barriers, for instance, high operational cost or transportation cost and legislation issues, they are categorised into same general groups about cost and legislation. Table 2.4 presented a summary of drivers and barriers for computer re-use listed in literature.

Table 2-4 Drivers and Barriers for Computer Re-use

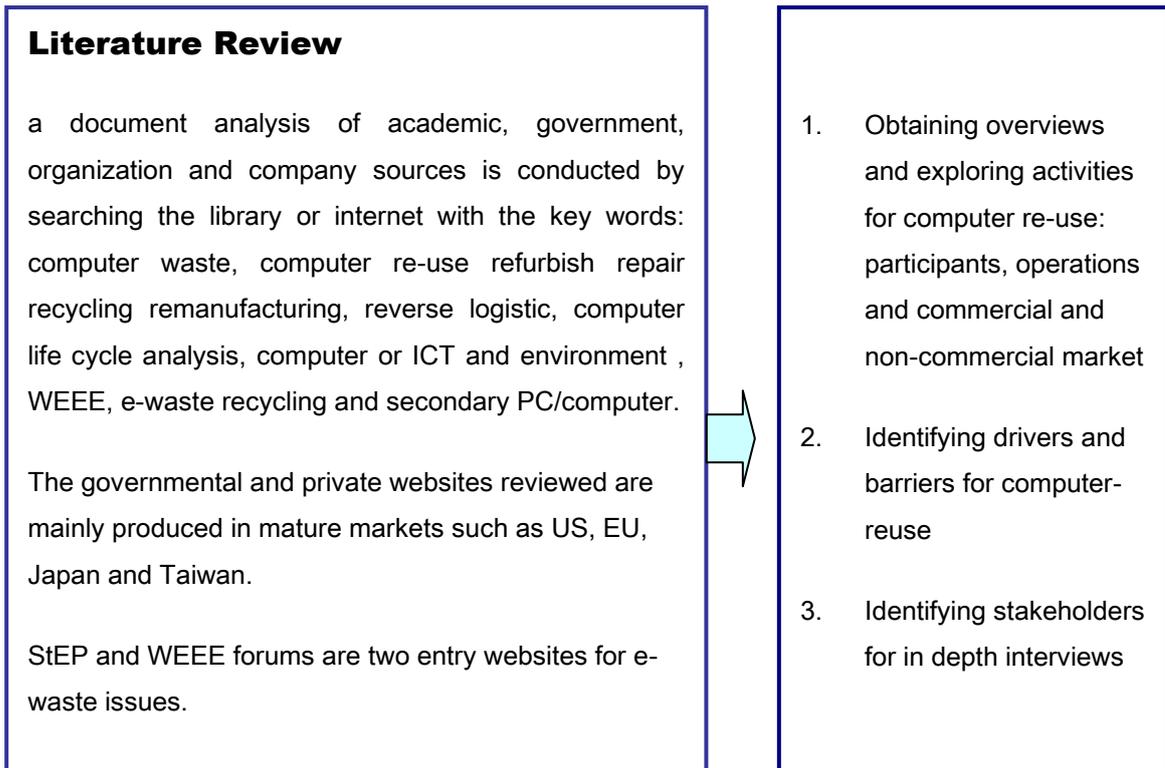
| Drivers | Barriers |
|------------------------------------|---|
| 1. Resource Conservation | 1. Small prices differences between New and Used PC |
| 2. Bridge Digital Divide | 2. Lack of Economies of Scale |
| 3. Benefits to Low Income Families | 3. Rapid Technological Development |
| 4. Profitability | 4. Legislation |
| | 5. Lack of Available Fleet Machines- High Volumes of Used PCs with Identical Configurations |
| | 6. High Operational Cost |
| | 7. Lack of Research and Development, Fragmented Industry and Groupings |
| | 8. Software Licensing |

3 Methodology and Analytical Framework

This chapter presents the methodology and analytical framework for this research. The first section provides the background about methodology structures conducted by this research. The second section explains the details for data collection and the stakeholder informations. The third chapter gives the framework of the particular categories this research works on.

3.1 Methodology Structures

Figure 3-1 provides the details to demonstrate how this research is conducted. It includes five main steps: 1) the literature reviews related to e-waste, computer re-use and secondary PC, 2) establishing the contacts of refurbishers and government bodies in Taiwan, 3) build the contacts with producers by checking the offices in Taiwan or other international materials for responsible persons, 4) Conduct the case study in Taiwan through stakeholder interviews, national data reviews and analysis of drivers and barriers among stakeholders and comparison of literature reviews 5) Provide the recommendations and conclusion based on discussions with stakeholders and other relevant research materials.



Establishing Ground Contacts

Semi-structured interviews with researchers and professors related to this study field in Taiwan.
Reach contacts through government projects of used PC donation for bridging digital divide

Exploring the recycler and refurbishers by assessing the database of computer repair, recycle, resell information in Arlink electronic shopping mall, Microsoft Authorised Refurbishers program, and Industrial Technology Research Institute



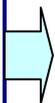
1. Assessing the primary and secondary PC commercial and non-commercial market in Taiwan
2. Identify key contacts for stakeholder interviews

Establishing Key Contacts of Producers

Review of secondary data: company' s profile, sustainability report, recycling programs and on-line CSR (corporate social responsibility) news

Approach two Taiwanese PC brand-Acer and ASUS and HP in Taiwan

Gather Dell and Lenovo contacts from member list of Basel Convention Partnership on Computing Equipment (PACE) and EPEAT Standards Development Roadmap Project.



1. Understanding the products, services, operational mode, strategies and recycling programs of companies
2. Design questionnaires and prepare for in depth interviews
3. Identify key contacts for stakeholder interviews

Case Study in Taiwan

In-depth and semi-constructed interviews with stakeholders: 1) Government bodies: Environmental Protection Agency, Environmental Research Institute, Consumer Protection Commission and Economic Ministry. 2) Organizations and Companies for non-commercial secondary PC (donation) 3) Recyclers for electronic products and refurbishers for computer repair resell and recycle. 4) Producers in Taiwan: Acer and HP

Review of secondary data: governmental project reports and recycling data

Analysis and discussion: literature reviews, discussions among stakeholders and researchers related to this field



1. Understanding the supply chain of secondary PC in Taiwan
2. Obtain the overview for secondary PC operations in Taiwan
3. Discuss and analyze drivers and barriers for secondary PC in Taiwan among stakeholders and compare with global situations based on existing data and literature reviews

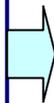
Recommendations and Conclusions

Review the main findings

Identify the common drivers and barriers perceived by stakeholders and the differences from literature reviews

Provide recommendations for three stakeholder groups, reviewing secondary data for approaches in other countries or discussions in literatures

Outline the potential topics for future researches



1. Outline the similarity and difference of secondary PC situation for national and global context based on the characteristics of Taiwan, highlights the key drivers and barriers perceived by stakeholders and the difference from literature reviews.
2. Make suggestions to three stakeholder groups based on the perspectives from different stakeholders and other relevant data researches.
3. Developing the proposals for the improvement of secondary PC market in Taiwan

Figure 3-1 Methodology structures of this research

3.2 Data Collection

In order to meet the objective of this research, the information are gathered by literature review, semi-structured interviews and in-depth interviews, either conducted in person or via telephones. The stakeholders included for interviews are government bodies, producers and refurbishers.

This research reviewed the corporate social responsibility reports of interviewed PC hardware companies and tended to assess the general practices of PC companies for secondary PCs. In order to understand secondary PC market in Taiwan, there are several semi-constructed interviews conducted among researchers or professors related to this field, PC dealers, distributors, system integration companies, refurbishers for donations and commercial sale, recycler, lesser, the service, sales, and financial service of OEM's company.

Snow ball sampling technique is applied for the identification of interviewees with government bodies. Through the semi-structure interview with Environmental Research Centre, the researchers explained the situations of governmental operations, the standpoints of government from their perspectives and made suggestions for potential informants. They are Environmental Protection Agency, Economic Affairs and Consumer Protection Commission.

Since each government body takes different responsibilities, there is no standard questionnaire applicable. The same holds for the producers; not all of the interviewed PC hardware companies have the refurbishing/remanufacturing operations for their take-back products or have partnership with refurbishers for secondary PCs. To gather perspectives from different governmental bodies and producers about secondary PCs, this research arranged semi-structured interviews for some prepared and open questions.

To identify the informants among refurbishers, this research used both snow ball sampling and stratified sampling. Non-commercial refurbishers are identified by the information of government projects. For commercial refurbishers, this research uses some semi-structured interviews with refurbishers to gain the background about various refurbishing participants and separate them into three groups as follows,

The questionnaires and surveys for the analysis of drivers and barriers are prepared for all interviewed refurbishers (Appendix A-1). Table 3.1 illustrates the information about participants of stakeholders (Appendix A-2: not included refurbishers requesting for anonymity).

Table 3-1 Participation of Stakeholders

| Stakeholders | Type | Number | Informants |
|--------------|-----------------------|--------|--|
| Producers | PC Hardware Companies | 3 | HP(Taiwan and Europe), Acer(Taiwan) ,and Dell(Europe and Sweden) |

| | | | |
|-----------------|--|---|---|
| Government Body | Environment, Consumer, Economic | 4 | Environmental Protection Agency, Environmental Research Institute, Consumer Protection Commission and Economic Ministry |
| Refurbishers | Non-Commercial | 3 | Triple-E, Tatung and ASUS foundation (for the understanding of donation projects) |
| Refurbisher | Commercial-collector, refurbisher, reseller (DT mainly) | 5 | Small sized refurbishers |
| Refurbisher | Commercial-collector, refurbisher, reseller and recycler | 4 | Small sized x2 and medium-sizedx2 |
| Refurbishers | Commercial-refurbisher (NB mainly) | 1 | Medium-sizedx1 |

3.2.1 Analysis and interpretation

For the semi-structured interviews with government bodies and producers, since government bodies have different responsibilities and producers run different operations, all their standpoints for drivers and barriers of secondary PCs are illustrated for the analysis and discussions. For the in-depth interviews with commercial refurbishers, the questionnaires presented the perceived drivers and barriers between weak and strong level. Additionally, the informants will be asked to answer an open question for each for the items evaluated. The later will provide valuable information about their insights that will help to justify the response. Due to higher similarity of commercial refurbisher group, the drivers and barriers perceived by refurbishers will be separated into three levels from high to low as follows,

- High: over 80% refurbishers (eight to ten commercial refurbishers) interviewed perceived it is a driver or barrier.
- Middle: 50%-70% refurbishers (five to seven commercial refurbishers) interviewed recognized it is a barrier.
- Low: 10%-40% of refurbishers (one refurbisher to four commercial refurbishers) regarded it as a barrier.

This analysis first uses the bar chart to identify the common drivers or barriers perceived by three stakeholder groups. The separated drivers and barriers will be recognized and discussed through the orders of government bodies, producers and refurbishers. The second part of the analysis is the comparative study to review the difference between literatures review and stakeholder surveys. The drivers and barriers not included in the literature review are summarised and presented.

3.2.2 Analytical Framework

Since various activities might be associated with computer re-use, this research identifies the areas through semi-constructed phone interviews and defines the focused area for the case studies. Figure 3.1 illustrated the activities (in circle) and actors (in square) associated with computer re-use and highlight the areas out of research scope by dashed line. This research

focuses on the drivers and barriers associated with the activities operated by refurbishers of commercial sales and donation and the asset recovery services offered by producers.

The semi-constructed phone interviews with ten lesser concluded that most of PC equipment leasing for private or public sectors is capital leasing that lessee generally pay 36months rent and obtain the ownership for continuing operation. Even though some PC leasing cases belong to operating leasing, those lesser perform no refurbishment after product returned by lessee. Therefore, this research didn't include lesser in the study of stakeholder perspectives. For direct sale from primary user to secondary user, internet auction and detail information about export, the author believes they are important categories for future works. As for actors only dealing with collection, reselling, or recycling, they do not have direct activities of refurbishment. This research does not include them in the survey groups.

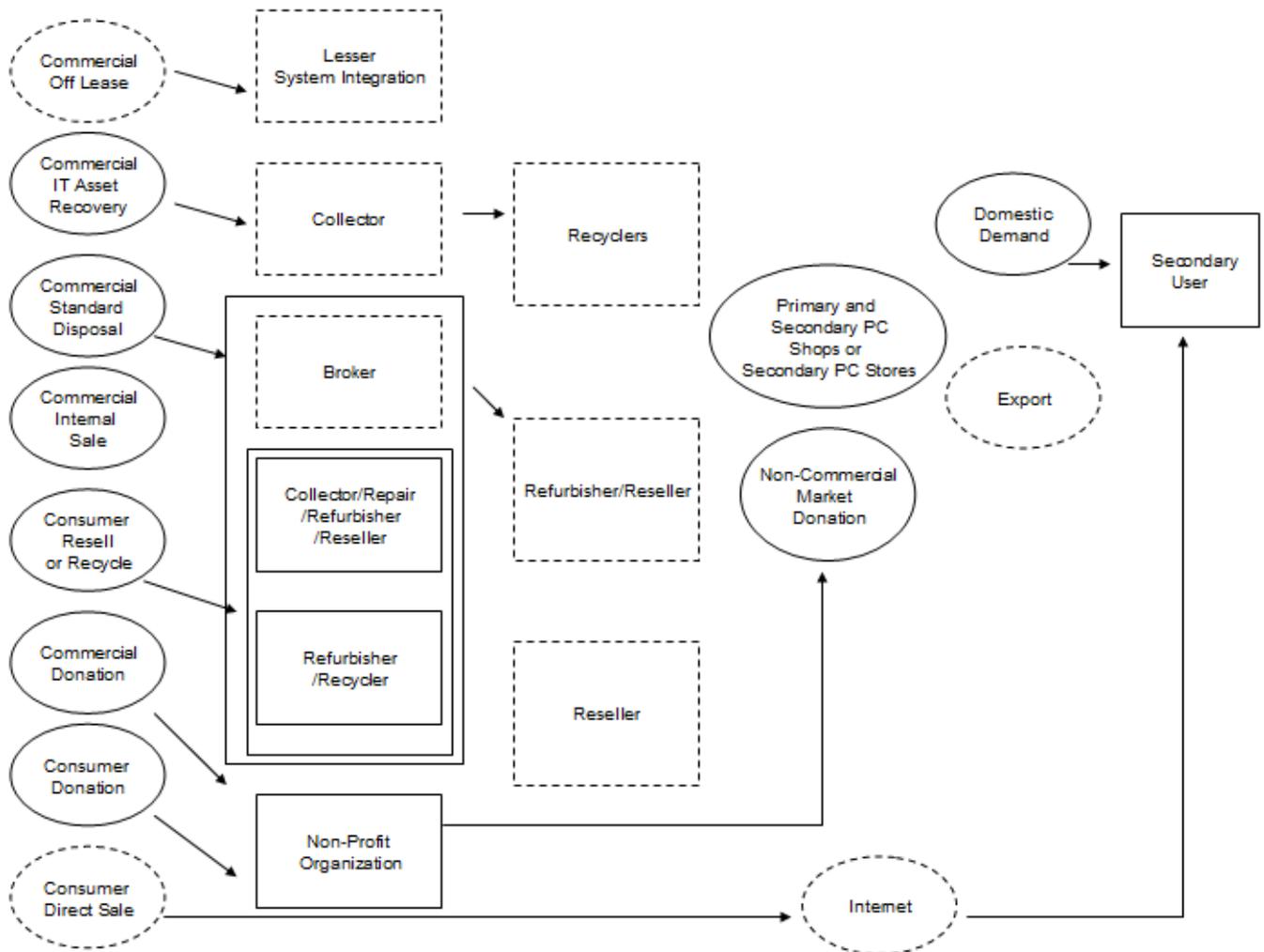


Figure 3-2 Analytical framework of secondary PC activities

4 Secondary PC Situation in Taiwan

Taiwan is located in Eastern Asia with its area 35980 square kilometres, bordering the East China Sea, the Philippine Sea, the South China Sea and Taiwan Strait. It is in the north of the Philippines, and is off the south-eastern coast of China. The population of Taiwan was around 22 million and its density is ranked as second highest in the world. Taiwan's rapid economic growth and quick industrialization in the decades after World War II had transformed it into an advanced economy as one of the Four Asian Tigers alongside Singapore, South Korea and Hong Kong. Taiwanese companies manufactured a large portion of the world's consumer electronics, although most of them are made in their factories in China. Unlike its neighbours South Korea and Japan, the Taiwanese economy was dominated by small and medium sized businesses, rather than the large business groups (CIA 2010).

In addition, Taiwan enjoys some particular features which can be summarized as follows (Huang, 2008),

1. Well established information, communication and transportation infrastructure
2. Highly populated, vigorous media and quick information dissemination
3. Various business services entities as well as sound and convenient virtual sales channel (express delivery, on line or TV orders and postal services)

They can be served as background to see how the case study of Taiwan can be helpful or applicable for other countries.

Taiwan has its strength and weakness on secondary PC market. There are no recent data to show overall secondary PC market in Taiwan. Higher demand in emerging market abroad gives incentives for refurbishers to export used PC. The estimated volume is 10,000 pieces per month. According to a thesis research in Taiwan in 2001, 78% of discarded IT product was sent to recycling plants, 14% to secondary market and 8% exported (Chang 2001). The sources for secondary PCs could be the functional PCs through secondary market, regular business practices between business to business (B2B) and business to consumer (B2C), consumer to consumer (C2C) or the electronic wastes from recyclers or collectors. Since IT products are defined as notified recycling items in 1998, producers must pay the recycling fee to Recycling Management Foundation (RMF) under Environmental Protection Agency based on their sales volume. When the products are retired, the primary users need to place their PCs at appropriate recycling channels for end of life disposal. When the users consider those retired PCs are still functional or have higher residual value, they will bring them to the secondary market mainly run by small business for higher collection fee. Though Taiwanese original design manufacturers (ODM) dominated around 90% of mobile PC global market, the production sites were mainly located in China (MOEA 2009). Owing to some constraints in local market (more discussions regarding the barriers for PC reuse could be found in Chapter 5), there are no large scale remanufacturing or refurbishing process associated with manufacturers or producers in Taiwan.

This chapter discusses the practices of secondary PCs in donation program and in commercial market separately. In commercial market, the two main areas are divided based on the point of sources. One area is discarded PCs from mixed sources such as consumers, recyclers or public and private sectors and another area is retired PCs from large corporation.

4.1 Donation

The rapid development of information technology in the global community has had a great impact. It not only has changed the lifestyle but has enlarged the gap more and more between urban and rural areas. The fast growth of economy and electronization has exerted different impacts on people with different socioeconomic background of sex, race, class, or residence. There were unequal opportunities for different groups to access the information and communication technology.

Government recognized the importance to give equal opportunities to the groups of woman, aboriginal, and physically and mentally disabled citizens. National Information Communication Technology Task Force in Executive Yuan, the executive branch of the government of Taiwan, proposed a four year plan to reduce the digital divide in 2004. Executive Yuan regarded this plan as one of major national policies and developed the program of e-Taiwan. The task groups included the urban-rural, industrial and international groups to improve the digital divide phenomenon yearly. In urban and rural areas, coordinated by the Ministry of Education, gathered 11 ministries to reduce the digital divide and created digital opportunities through the setup of infrastructure, development of community, service learning, e-based government service, and promotion of culture and creativity, and industrial development. Taiwan Environmental Protection Agency (EPA) was one of 11 ministries and initiated the program of used PC donations for resource conservation together with combating digital divide objective. This program invited individuals, groups or business enterprise to participate actively. EPA issued the governmental letter to both public and private sectors for their cooperation to donate their used PC. This re-use program was run on a yearly basis. The advertised bidding was organized by the EPA to select a yearly operator (either an organization or private company). This operator received governmental funding to support overall activities from surveys, collections, refurbishments to services. "Your old computer to his new hope" was the annual event of 2009 focusing on the aboriginal children operated by Triple-E Institute (Triple-E 2009). Through the governmental initiation program, EPA plans to raise public awareness to support this kind of event and brought more business sectors into the PC re-use market.

According to the market survey done by the operator of the 2007 (CIER 2007), the penetration rate of PCs in Taiwan was 85% in cities ranging from 70% to 90% and from 60% to 70% in rural areas. Average showed every 7.8 out of ten houses had own computers. The penetration rate of internet was 70% in cities ranging from 65% to 80%. Internet in Taiwan had slightly shorter history - around 7 year - than 8.34 year of a PC. The survey estimated secondary PC demand was 10,000 units per year. Table 4.1 illustrates figures about PC penetration status in Taiwan. The PC installation base per 1000 persons was closed to 500 units lower than figures available at Gartner (2009) for Japan, Western Europe and U.S. markets. By looking at figures of PCs per 100 households, over 85% families had a desktop PC but not every family member would purchase a desktop PC or a mobile PC for his or her own.

Table 4-1 Personal Computer Installation Base in Taiwan (Unit: per piece)

| Categories | Year 2007 | Year 2006 | Variation |
|----------------------------|------------|------------|-----------|
| Total PC Quantity | 11,297,500 | 10,415,285 | 882,215 |
| Household | 6464956 | 6,149,480 | 315,476 |
| PC per 100 Households | 87 | 84 | 3 |
| Public and Private Sectors | 4,832,544 | 4,265,805 | 566,739 |
| PC per 1000 persons | 492 | 457 | 35 |

Source: CIER 2007

The objective of this project is to redeploy of used computers through disassembly, testing, processing and reassembly and donate the remanufactured PC to rural areas for reduction of urban-rural digital divide. The specific content of the work can be divided into four categories as below,

1. Establish recycling mechanisms for secondary PCs: the set up of collection points, information platform, and recovery management system.
2. Build a standard operation procedure for remanufacturing of secondary PCs: the inspection, clearance, software and hardware testing and waste controls.
3. Develop a standard procedure for installation process: the identification of recipient , the logistics system, the training and warranty, and the evaluation of performance.
4. Demonstrate the procedure to recycle used computer for donation: campaign, international experiences sharing, donation ceremony, and award certificate.

From 2005 to 2009, the total number of recycled computers was 65000 units, and remanufactured computers for donation were 16800 units. It is around 0.4% of annual desktop PC shipment.

In the mean time, ASUSTek Computer has been coordinating a scientific project under the Ministry of Economics in the year of 2008 to 2010 for computer donations. The donors could be both business sectors and private customers. In business sectors, they are public enterprises, government bodies, schools, private enterprises, and corporate companies. The updated status of donation from donors has been open in public website. It encouraged donors to actively participate to enhance their branding images. Donors sent the used PCs either to direct ASUSTeK service centres, selected recyclers or key channel stores. They also run some special events on the Earth day with university partners, and promote recycling in Taiwan Semiconductor Manufacturing Company.

Components with higher defective rates were hard disk drive, power supply, and motherboard. During disassembly, testing and reassembly process, Operators would not purchase new key components but select the working components and reassemble them into one functional PC. In general, the refurbishment rate for above projects was around 20% to 25% which meant four used PCs were disassembled and reassembled to one refurbished PC.

In addition to the donation programs initiated by governments, there were other donation processes between customers and system integration suppliers in place. Government bodies may request their system integration provider to take back the used PCs and refurbish them for donation. They generally place order in large quantity with same specifications. The request for donation may or may not be listed in the original purchasing contract. Government bodies pay certain operational fee to cover suppliers' expenses. However, they were still a costly project for suppliers if it was not covered by contract agreement. The recent case was the supplier took back 5000 units produced in 2003 from Taiwan Research, Development and Evaluation Commission. Supplier, also the producer, prepared the spare parts based on service records and tried to reach 80% refurbishment rate. The refurbishment cost per unit was around \$100US including one year warranty.

4.2 The commercialized market: second-hand market

The second-hand markets in Taiwan are mainly operated by individual refurbishers and small-medium refurbishing companies (employing between 2 to 50 people and annual revenues less than US\$3 million)(SMEA 2010). Internet based auction of individual buyers also accounts for certain percentage of secondary PC market.

According to the database of Arlink, the largest IT product market of Taiwan, there are around 2000 shops running the business of PC repair and buy-sell secondary PCs.

Based on the interview results and literature review for identified actors and activities in analytical framework, this section introduces first the practices of collectors/refurbishers/recyclers (resellers) who receive used or discarded PC mainly from private consumers or other public and private institutional users, and it then explains the practices of medium size refurbishers who only handle the retired PCs from large corporate customers.

Collectors/refurbishers/recyclers (resellers) with less than ten employees normally sold around 10 pieces to 100 pieces per month. For the quantity up to 100 pieces per month, PCs are mainly exported to other Asian countries. Most of refurbishers who have skilful technicians for the disassembly, testing, parts replacement, repair and reassembly of PCs focus on desktop PC refurbishment. They also provide other services such as the collection of retired PCs for recycling, PC testing/inspection/repair/upgrade/software installation, new PC sale, or website setup. To run this kind of small business, it is not required to get the certificate although it is preferred by customers. Bureau of Employment and Vocational Training issues certificates of level B and level C technician for computer hardware fabrication (EVTa 2010).

4.2.1 Generic Sources for Secondary PCs

The refurbishers with less than ten employees receive the discarded PC from various sources.

1. The working or non-working machines from private consumers. For working machines, they would provide the quotation to private consumers, based on the specification of processors, motherboards, memories and hard drives with the reference of internet sales price. For non-working machines, if consumers intend to repair in the beginning, they would offer the quotation and let customer decide to repair or not. In most of cases, the repairing prices for customers could be very high for an old and out of warranty machines. To repair a desktop motherboard may cost \$30USD but purchase a new one with higher specification may be only \$40USD. When consumers choose not to repair, they would pay for the recycling fee around \$5USD per system and verify later if the systems or components are worthy to repair or reuse for secondary market. Most of resellers accepted the used and functional computers less than four years old for a mobile PC and five years old for a desktop PC.
2. Collectors and recyclers: Collectors collect the used PCs from households, public or institutional users. In Taiwan, there are in total 100 collection companies for IT products and 14 recyclers with recycling treatment plant facilities.
3. The municipality collectors: the collectors collect the used or discarded recycling items from households. It is a district service twice per week. Recyclers do annual bidding to get those used or discarded items for reuse, resell or recycling from municipality collectors.
4. Self assembly with out of warranty or used components by refurbishers (Desktop only)

Table 4.2 and Table 4.3 provided an overview of warranty period that producers offered in Taiwan and component levels in general. For component level, the warranties offered by supplier are different from brand and price.

Table 4-2 PC system warranties in Taiwan

| PC Brand/Type | Desktop PC | Mobile PC |
|---------------|------------|-----------|
| Acer | 1 year | 2 year |
| ASUS | 3 year | 2 year |
| HP | 3 year | 1 year |
| Lenovo | 3 year | 1 year |
| Toshiba | n/a | 1 year |
| Sony | n/a | 3 year |

Source: TKEC 2010

Table 4-3 Component warranties in general

| Component | Desktop PC | Mobile PC |
|-----------------|----------------------|----------------------|
| Motherboard | 2 to 3 years | 1 to 3 years |
| Memory | 1 years to unlimited | 1 years to unlimited |
| Hard Disk Drive | 1 to 5 years | 3 years |
| LCD | 3 years | 1.5 years |
| Power Supply | 1 to 5 years | 3 years |
| Optical Drive | 1 year | 1.5 years |

Source: TKEC 2010

Refurbishers check the functionality of system hardware, clean the dusts on components and housing, and then repair or reassemble those components back to working condition. After the hardware process, refurbishers install software based on customer requirements. Some refurbishers install testing programs for long run testing in order to ensure the reliability of overall system. Average time required for refurbishing a unit vary depending on refurbishers. Some refurbishers would take 2 to 3 hours or 8 hours including system long run testing.

For a broken PC, desktop PCs are easier to be repaired than mobile PCs because they consist of parts common across different brands than mobile PC. If components are in shortage or out of supply, the refurbishers would check with their colleagues for availability. For a mobile PC, another problem is the difficulty in disassembly. Refurbishers need to double check with their customer if they want to repair those out of warranty mobile PCs. The service centre of producers would not take any responsibility once notebook was disassembled by third party refurbishers.

For the case of shortage in mobile PC unique items, they would not purchase the spare parts from PC producers because of associated high cost especially for old models. The defective systems would be just disassembled for the components reuse and then unit recycling. Figure 4.1 shows the flow of used PC and components.

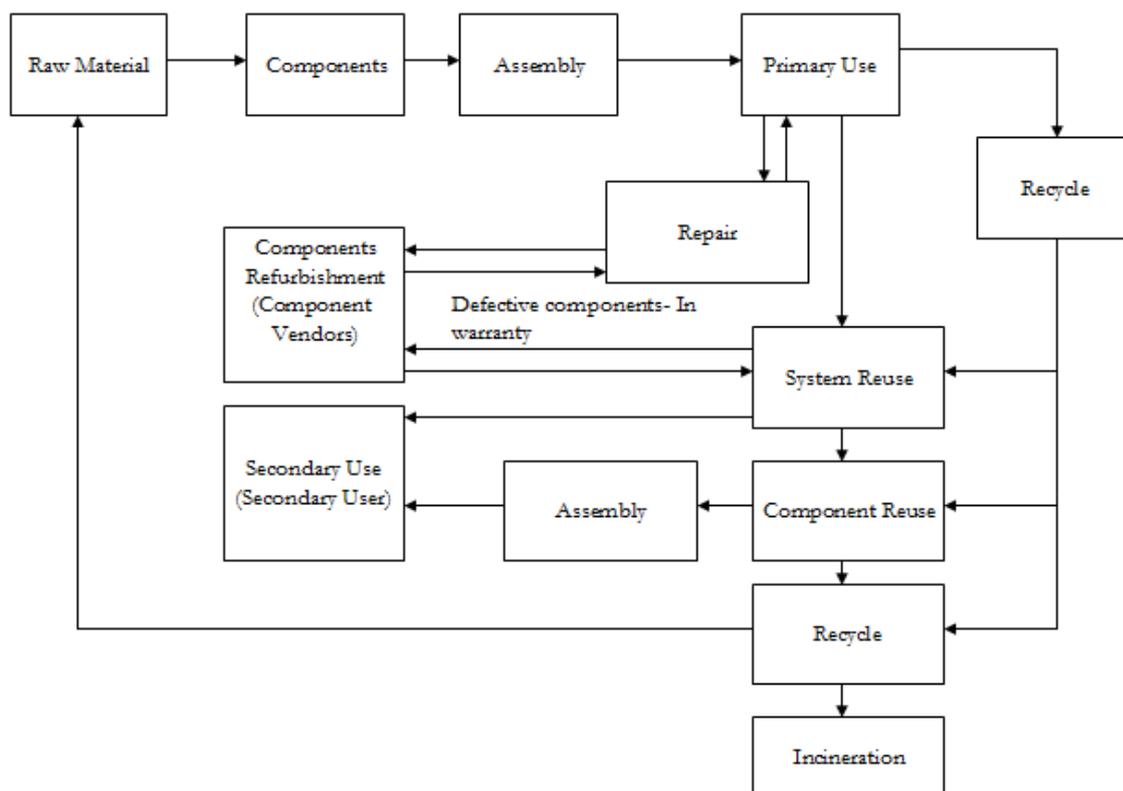


Figure 4-1 Reuse flow of PC and components in Taiwan

There is no specific warranty period offered by refurbishers. A few refurbishers make their decisions depend on the final deal of the sales price. If the customers ask for higher discount, they would not offer any warranty. Other refurbishers offer seven days to three months warranty.

The collectors/refurbishers/recyclers sometimes receive the orders in a range of 30 units to 100 units from resellers or dealers. They either order those units to export to developing countries or to some factories still running with old IT system.

4.2.2 Sources from Large Corporation

Another type of players in Taiwan secondary PC market are brokers/refurbishers who only collect used PCs from Global 500 enterprises¹⁰ and sell the refurbished PC to dealers in Taiwan or abroad. One medium-sized refurbisher only deals with the PCs from enterprises for the ease of handling. They have regular contracts with Global 500 companies in Taiwan, Hong Kong and China to collect used machines every two to three years. Those Global 500 companies have central IT procurement and they normally purchase or lease HP, Dell or Lenovo commercial machines on a regular basis. Those used systems from enterprises resulted in higher stability and similarity. HP, Dell and Lenovo helped to engage the refurbisher with their global 500 company customers for more professional and safer handling process from data destruction to final recycling. Those international companies have more concerns for the disposal stages of used IT than national enterprises. It was similar to the asset recovery

¹⁰ top 500 corporations worldwide as measured by revenue. Fortune magazine compiles and publishes the list annually.

services that HP, Dell or Lenovo offer in mature market such as USA, European countries or Australia. Producers like HP and Dell have stronger market position in professional PC market than with private consumers. They build partnerships with qualified refurbishers or recyclers for this service. The medium-sized refurberisher sells secondary desktop and mobile PCs to dealers in Taiwan and customers from emerging markets all over the world such as Middle East, Asia or India.

The monthly sales volumes of the medium-sized refurberisher is around 1000 units with the proportion of 50% desktop and 50% mobile PC. The domestic market accounts for 30% of their sale and remaining 70% is for export. However, the medium - sized refurberisher mentioned they still get pressure from either producers or recyclers on secondary PC domestic market.

The medium-sized refurberisher has two types of quotation process to obtain the sources of used PC. They collect the used systems from enterprises first and provide the buying price based on the testing results. One functional PC could cost \$100US to \$200US. If enterprises prefer to sell the machines without prior testing, the price would be lower and negotiable. The number of total employees in the medium-sized refurberisher is 16 including the operators. It takes around 8 hours to refurbish one computer according to its standard operation procedure. They receive the documents of service manuals from producers and start the refurbishing process. The refurbishment rate can be around 30% if most of sources from enterprises have functional issues or up to 90% if used PCs are retired while end of service life. Their customers have different requirements such as battery life or warranty. Though they have sources that provided used PCs with higher quality, they operate with stricter refurbishing requirement. Their profits are less than 50% compared to small refurbishers. Table 4.4 provides a summary of refurbishment operated by different types of refurbishers

Table 4-4 Summaries of refurbishment by different types of refurbishers

| Categories | Collector/Refurbisher/Recycler | Collector/Refurbisher/Reseller | Refurbisher |
|-------------------------|---|--|---------------------------------------|
| Sources of Used PC | Public or Private Sectors or out of warranty components | Consumers or Public or Private Sectors or out of warranty components | Global 500 enterprises |
| Recovery Time per Unit | 3 hours | 2-8 hours to 3 days | 8 hours |
| Recovery Rate | 20%-30% | 30-40% | 30%~90% |
| Average Sales Quantity | 30-100 units/month | 5-10 units /month | 1000 units/month |
| Average Ages of Used PC | 4-6 years | 4-6 years | 3-4 years |
| Target Customers | Domestic market or Export | Domestic market-low budget customer or beginner user | Domestic market (30%) or Export (70%) |

5 Stakeholder Perspectives: understanding the drivers and barriers

This chapter presents the perspectives of identified stakeholders about secondary PC market and its drivers and barriers. Their perspectives are presented in the original form without interpretation. Some suggestions were also discussed during the interviews or surveys. They will be discussed in the next chapter. The first sections are the point of views of government bodies, the second section concerns comments from producers and the third section, opinions of refurbishers. The final part of this chapter summarises the drivers and barriers perceived by stakeholders for the analysis and discussion in the next chapter. In the beginning of the interview, the stakeholders were asked to present their views about secondary PCs and their market. It was followed by the assessment where stakeholders were asked to rank listed drivers and barriers between strong and weak.

5.1 Government Bodies

5.1.1 Institute of Environment and Resource

The Institute of Environment and Resources (IER) was established in 1993 to conduct policy research and communicate results to the government and public. IER acts as a think tank for environment policy research and advisory unit for long-term implications of sustainable development in Taiwan (IER 2010).

The researchers in IER are aware that the activities of computer reuse exist but they consider it would be hard to trace due to many uncontrolled sources such as internet auction or individual refurbishers. The individual collectors or refurbishers may not apply business license and those secondary deals are normally not included in sales record. Most of consumers may not require the receipt either. To obtain clearer figures on used IT products, EPA started to work with mobile phone distributors and dealers for the information on collections of used mobile.

They regard bridging digital divide and resource conservation as strong drivers for the promotion of secondary PCs. On the other hand, the safety and regulation, lack of economy of scale, and the low price difference between new and secondary PCs are strong barriers. Not enough exploration of the benefit of reuse and too much focus on recycling are other strong barriers as well. More studies on the ground level can be helpful.

From their perspectives, it is hard to define what kind of regulations or safety requirements should be applied for secondary PCs or other used products. They give used tires as an example, the safety issues of which could be really critical. There was no international standard for refurbished PCs. The mobile phone working group of Basel convention was currently establishing the standard for the refurbishment of used mobile phones but the researchers perceive that the computer sector is in much more complex and the status is still unknown. Since various types of used PCs are collected, it is almost impossible to require the same standard as new systems. They consider that the testing or certification fee could be much higher than the residual value of secondary PCs. Moreover, the launch of low cost computers or netbook has made the price difference lower than \$150US between new and secondary PCs. Since there is no independent study about the situation on secondary PCs, this grey area limited further approaches or developments for secondary market.

5.1.2 Environmental Protection Administration

Environmental Protection Administration (EPA) was upgraded from Environmental Protection Bureau, the Department of Health in 1987. EPA governs seven departments and Bureau of Environmental Inspection and funds management boards including Recycling Fund Management Board (RFM), Environmental Analysis Laboratory and Professionals Training Institute. To achieve zero waste by recovering resources is one of five main strategies of EPA (EPA 2010).

The group leader of RFM in charge of the category of electric and electronic products expressed that EPA considers the reuse in their policy and has supported the programs of used PC donation since 2002. The reason for reuse not included in waste management policy is because reused products would be recycled eventually at the end of life stage. Therefore, they focused on the establishment of recycling mechanism at the first place. Issues such as difficulties in defining residual value and lack of safety standard are main barriers for EPA. As for donation programs, he concerned most about the high cost for the refurbishment and the rapid technological updates that increases the difficulty for computer reuse. Meanwhile, the demand for refurbished PC is also uncertain for him. When the price difference of new and used PCs becomes less and less, he thought the demand should be re-evaluated. However, he states EPA still encourages the public to support continuous donation events initiated by NGO groups.

5.1.3 Consumer Protection Commission

Consumer Protection Commission (CPC) was established in 1994 under Executive Yuan, the executive branch of the government, in accordance with Article 40 of Consumer Protection Law. CPC integrates, coordinates, monitors and plans the promotional works concerning consumer protection in Taiwan. The CPC's primary duties include drafting consumer protection policies, and outlining and reviewing consumer protection programs and projects. In addition, it studies draft revisions of consumer protection statutes and is also responsible of the establishment of consumer protection mechanisms (CPC 2010). CPC refers to the United Nations new guidelines of consumer protection released in 1998 and has six primary principles to transform consumer toward sustainable consumption.

In their views, the secondary PCs correspond to the main objective of CPC -that they encouraged consumers to purchase those products with lower environmental impacts. Another motivation for CPC is also to provide the benefits to consumers in disadvantageous positions. CPC promotes green products that strive for the design for recyclability and reuse. As long as the safety and functionality of the secondary PCs can be fulfilled, CPC supports that the secondary PC market should be strengthened. Other issues such as after service and consumer education are important factors that governments can act as the intermediary to develop some contract guidelines. So far, there was no such record of customer complaints particularly on secondary products. However, the complaints on online shopping cases have been increasing overtime. CPC manager mentioned the setting of case entry in the database can be modified to differentiate the new and second-hand products for a better tracking in the future. In recent years, there have been some cases indeed about fake products in which producers assembled used components with new housing and sell them as new products. Government bodies reached consensus to regulate this kind of products and set the penalties on producers. As for secondary products, government did not set any standards and regulations yet.

5.2 Producers

In regards to the interviews with producers, Hewlett-Packard (HP), Dell, and Acer offices in Taiwan were approached. However, as highlighted in the section of scope and limitation, the author cannot get responses from Dell Taiwan. Dell Europe and Sweden was interviewed instead. In the mean time, to obtain corresponded data as comparison with Dell Europe, an interview with HP Europe is conducted further. This section provides the standpoints of producers which are HP in Taiwan and Europe, Acer headquarter in Taiwan, and Dell in Europe and Sweden. All producers have very clear messages for secondary PCs both in non-commercial market and commercial market.

5.2.1 Non-commercial market

Producers in Taiwan prefer to donate new computers to low income families or disadvantage groups as they concern the after service of used computers. Both Acer and HP donated their new PCs to support the families affected by the flood in summer 2009. HP manager mentioned that the donation should not just to give away a used PC to those families but the appropriate software and relevant infrastructure should be ready at the same time. It can also be questioned that those disadvantageous groups should receive old products just because of their inferior societal and financial positions. Because of the modernization in different countries, Acer manager explained that used PC donation is trickier in Taiwan than other Asian countries such as Philippine or Vietnam. The media environment was another concern for some producers to support the donation of used PCs. The good intention probably would be manipulated to something immoral.

5.2.2 Commercial market

As for commercial market for secondary PCs, producers have not participated in the operation or sales business actively. Acer and HP explained the main reasons are brand images due to the uncertain quality of used and refurbished PCs and high service cost. They also have other concerns such as safety problems and old PCs containing higher toxic substances. Dell manager in charge of take-back program in Sweden pointed out the requirement to refurbisher that the refurbished PC must be 100% functional. Otherwise, it needs to be recycled or designated to be reused at the component level.

Dell Sweden explained that private customers can choose to recycle their used PC through municipality channels or contact Dell to recycle their used product for free. The used machine from customers would be handled by eligible recycler partners of Dell. Dell Sweden also provides the free service to any customers to recycle any brands of used PCs when they purchased a new Dell machine. For commercial customers, customers can choose to recycle their retired machine through recycler partners. The difference between commercial customers and private customers are that commercial customers need to cover the transportation cost and two kinds of options are offered to them. One is the system recycling in which retired machines are sent to recycler partners for recycling. Another one is the asset recovery service that Dell offers to help commercial customers to wipe their hard drive data on site or off-site and resell their machines through refurbisher partners. Dell charged the service fee for hard drive data sanitation but had no profit sharing for system resold. Dell Sweden manager highlighted it has not been their core business. The refurbishments have taken place only in some cases when commercial customers discard their machines. Most of the PCs collected from private customers are very old like seven years which had no residual value for refurbishment.

Acer Corporate Sustainability Office (CSO) director mentioned that apart from local or regional requirement found in safety regulations about Electromagnetic Disturbance (EMI) and Electromagnetic Compatibility (EMC), the most critical issue would be the safety concern of mobile PC batteries. In his opinion, the battery in a three-year-old mobile PC would be most likely not working. If refurbishers replace the non-working battery with other non-qualified battery sources, it might create the risk of burning or explosion. In the worst case, it could lead to a house fire.

In Taiwan, for commercial and private customers, producers are financially responsible for taking back their products. Refurbishers and recyclers have no direct connections with producers. For the Asian market, HP sets their service operations in Singapore in which they only operate the reuse or refurbishment of components. The environmental manager highlighted that the recycling scheme in Taiwan shall be targeted to individual producer responsibility where producers can have better control on the end of life treatment of their products and make sure they are handled through a safe and sound process. Another problem the manager mentioned is that the current recycling scheme has no incentives for users to recycle their used products. When users pay over \$1000US to purchase those Information Communication Technology (ICT) equipments, they simply just feel reluctant to recycle it. ICT equipments are much smaller sizes than home appliances such as washing machines or refrigerators users would return the old machines when they purchase new ones. However, users just keep their old ICT equipments in the storage or closet. It is important for the recycling scheme to distinguish the different characteristics of electronic electric equipment in order to have efficient recycling management.

HP environmental manager in Europe and Acer Corporate Sustainability Office director both state that the collection rates through producer take-back channels are very low. In Europe, HP sold 350000 tonnes last year, which corresponds to around 40000 trucks, but only took back around 80 trucks. It was just 0.2% of yearly sales volume. For private users, most of the old PCs are still stored in houses or garages. The average age of used PCs collected from private households is around seven years old. For commercial customers, the retired machines are mainly collected by brokers. Compare to HP with much higher overhead, those small companies that they are flexible with only 20 to 30 people offered good price to collect those discarded PCs. Upon customer requests, HP provides the asset recovery service to business customers as well. However, the volume has not been significant. When customers request for this service and choose the option of trade in or resell, HP takes back the old equipment from customers and resell to brokers with unit price approximately \$60 to \$70\$US. HP manager emphasized that the rapid technological development and small price difference between old and new machines gives no incentives for them to participate in the business of refurbishment. For some high end products such as servers or printers, they do have refurbishing operation. In the case of Acer, they jointed a voluntary take-back program in India that offers private customers free take-back service but the collection rate of e-waste has been zero so far. As regards asset recovery services for business customers, he mentioned Acer has been strong in its consumer sales channel. When the commercial sales account for 30% to 40% of its total sales, it would be just worthy to evaluate the asset recovery services to commercial customers.

5.3 Non Commercial Refurbisher

5.3.1 Triple E Institute

Triple-E Institute has established in September 2008 as a non-profit social organization. The aims of the organization are to engage themselves in the sustainable development in the area of energy, environment, and economy, to research and develop think tanks, organise conferences, and exhibitions, public events and educational and social activities (Triple-E 2009).

The project manager in charge of donation of used PC considered the strong drivers for non commercial secondary PCs are legislation and benefits to low income families. He highlighted that the donation would not only conserve the natural resource by extending the life of used computers, but bring the caring and love messages of the public and government to the disadvantaged groups in society. Those groups should be provided with equal opportunities and cannot start behind the others. Computers could also be an interactive tool between parents and children where they share what they learnt and experienced. He also mentioned the government or producers should not underestimate other benefits of computer that users would enjoy such as connection to the internet and other PC peripherals which may improve the economical situation. He does not regard the donated PCs as a threat to PC producers. Most of low income families he visited have no intention to purchase secondary PCs even though the price of used PCs may cost only \$100US. They felt it is not necessary for them and the electricity cost could be a burden. The project manager communicated with families who mentioned that computer was a good tool for children to practice English and Mathematics and normally use it two to three hours per day.

The strong barrier for donation is the price difference of new and used computers. Other governmental projects also donated new netbooks to the families or students in rural area. One netbook costs around \$300US. The average cost of one refurbished PC is over \$200US. The price difference became less than \$100. The expense for government or organization on PC refurbishment may not be so well justified when looking at the situation from purely economic point of views.

High transportation cost is also a significant burden for the operation. The collection, distribution and on-site warranty service also add to the cost of transportation costs. In the case of government project which was operated by ASUSTek, they prepared some working system as buffer stocks for replacement in case any system defect is reported. However, the transportation costs were still the highest one accounting for almost 50% of operation. The refurbishing centres for donation are located either in North or South Taiwan. However, the sources of retired PC are located in all the cities across the nation. The costs appeared from consumers to collection centres were also significant. Project manager tried to reduce the transportation cost and ease the donation process of consumers by working together with one key dealer. However, the limited warehouse space of dealers could not keep those retired PC for a long period. It also caused a burden for project manager to transport those PCs to the refurbishing centre timely.

Low customer willingness to donate their used PCs and lack of incentives for enterprises are other two obstacles to receive sufficient number of used PCs for refurbishment. PC donation cannot be tax-reductive in Taiwan. Customers have low motivation to donate their used PCs. They may have several reasons such as data back-up and destruction and functional defect for their used PCs. The donation run by ASUSTek provides a bonus coupon of \$60US for consumers to donate their used PC. However, total number of private customers participated has been 700 people. It is less than 4% of total donated units. For enterprises, they normally

prefer to recycle or resell their used PCs to recyclers/refurbishers and they can get net benefits in their accounts.

However, for those enterprises donating their retired PC, the strong incentives for them are that it is easier to donate used equipments than dispose them. It would promote brand image. They are ranked based on the volume of donation in the project website.

5.4 Commercial Refurbishers

This research conducts interviews with 10 commercial refurbishers for the understanding of drivers and barriers in secondary PCs. Strong drivers are identified and agreed based on the feedbacks from over 80% refurbishers (equivalent to eight to ten refurbishers). On the other hand, barriers are presented in an order from the degree of high to low in terms of the percentage of refurbishers expressing the perspective factors,

- High: over 80% refurbishers (eight to ten refurbishers) interviewed perceived it is a driver or barrier.
- Middle: 50%-70% refurbishers (five to seven refurbishers) interviewed recognized it is a barrier.
- Low: 10%-40% of refurbishers (one refurbisher to four refurbishers) regarded it as a barrier.

5.4.1 Drivers

There are three main drivers recognized by refurbishers on secondary PC business.

1. Profitability.

Secondary PCs often offer better profit margins for refurbishers or resellers than new PCs. The profit margin ranges from 30% to 50% depending on the purchasing price refurbishers have to offer for the retired PCs. If there are any problems on used PCs and customers decide not to repair and have willingness to recycle, refurbishers purchase them at the price of recycling fee (\$4-\$5US per machine). The margin can be up to 50%. If refurbishers collect retired PCs from enterprises, the buying price would be based on working condition of the used PCs. If a retired PC works properly, refurbisher pays several hundreds for one unit. For this kind of situation, the margin per unit is around 30%. In general, the margin to sell a new system for a dealer is around 10%.

2. Benefits to low income families or budget customers

Most of the refurbisher interviews think that not all the customers need the latest technology, especially for the beginners. Some students or office workers may not have enough money to buy new PCs. For the group of people, secondary PCs would be a good option. It could benefit low income people or families when they wanted to purchase a PC but had only limited budget. Netbook in secondary PC market is also popular. Some customers purchased netbooks but resell them when they feel netbooks cannot fulfil their needs. Those second-hand netbooks have quick turnover sometimes shorter than one week.

3. Resource Conservation

Most of refurbishers understood the resources were limited. When some components or machines are still workable, they should be reused. Resource conservation is one of main drivers for refurbishers to manage secondary PC business. Refurbishers have the technical background to repair and refresh old machines as well as act as collector, recycler or reseller, and among these activities they could prioritise their refurbishing business.

5.4.2 Barriers

Refurbishers mentioned the following factors affect the secondary PC business in Taiwan. They are placed in an order from the degree of high to low in terms of the percentage of refurbishers expressing the perspective factors,

Since this research didn't conduct the interviews or surveys of users, barriers such as user knowledge, inadequate pricing and taxation system identified in literature review are not discussed here.

1. High Operational Cost - Transportation and Labour Cost

The transportation cost of collections or services is one of the main issues for most of refurbishers. If there is a problem on a refurbished PC, the round way transportation costs for the service on a desktop PC would be almost equal to the profit they could get. For a medium sized refurbisher, the transportation costs are slightly lower than labour costs and utility costs. In most of cases on exporting refurbished PCs, their quotations do not include the transportation fee.

Labour cost is considered to be burdensome for small or medium scale refurbishers. The testing process to verify each used component or system is time consuming. It takes several hours to complete the process of testing and re-assemble one unit. If there are more employees, the tasks will be divided and the total output can be higher. It is not possible to do a complete testing based on current operations and limited technical resources provided by producers. For example, if there are four USBs, they would test two USBs. The hard disc drive (HDD) wiping also takes lots of time. In most of the companies, they may have only one employee to handle management information system (MIS). The MIS has no bandwidth to manage those discarded machines properly. The medium-sized refurbisher even had a business discussion with US customers to collect their retired PCs and transfer to China due to lower labour costs for refurbishment. However, according to the Chinese Legislation, it is prohibited for this type of transaction.

2. Small prices differences between New and Used PC

Another main barrier for refurbisher is the launch of netbook delivering a wrong message to customers that the average price of a new computer only cost around \$300US.

When their resellers tried to sell a \$200US or \$250US three year old Dell or Lenovo 15 inch commercial PC, they constantly get the questions from customers why their price for a secondary PC is so high.

Most of interviewed refurbishers also run the business of selling new PCs or components. They mentioned that when the price difference between new and used PCs or components become less and less, they are forced to sell new PCs or components. In this situation, there is no incentive for customers to buy the used components or PC.

3. Low Collection Rate (Lack of available fleet machines-high volumes of used PCs with identical configurations)

Most of the refurbishers feel consumers have no strong incentives to resell or recycle their used PCs. The recycling fee does not encourage consumers to bring their used PC to those collection points for recycling. Some defective PCs are stored in users' home for years before recycling.

As for commercial users, refurbishers handling the retired PC from large corporations expressed that the demand for the secondary PCs is over supply and that they cannot get enough retired PCs from sectors to fulfil their back orders. Most of public or private institutional buyers don't replace their PCs on a regular basis. In many cases, employees continue working with old PC until they are broken. The average age of PCs that come to the refurbishers from the institutional users is five or six years old and they had very small residual value for resell. There are many obstacles to obtain those retired PCs for refurbishment and resell from public institutional users. The economic recession is also one of the reasons that private institutional users would delay their PC replacements.

4. Lack of Economy of Scale

Most of refurbishers concerned that lack of economy of scales for secondary PCs in Taiwan is one of major barriers. The accompanying high operational cost poses a burden for sound refurbishment and recycling.

5. Cost and Availability of Spare Parts

Cost and availability of spare parts particularly for mobile PCs are one of key problems for refurbishers to repair or refurbish those used computers. The fact that a mobile PC consists of many unique items makes it hard to refurbish. Refurbishers also wouldn't consider purchasing those spare parts for three - or four - year - old computers from producers because of cost concerns resulting from yearly mark-up of those component prices. In general, refurbishers try the approaches of checking if there are any similar or same models on stock, asking other recyclers or refurbishers or providing samples to component suppliers for new part production in case a large amount of the same component is required.

6. Unreliable Sources

The quality and origin of sources are also one of the bottlenecks for most of refurbishers. This is the key reason the medium - sized refurbisher focuses only on the retired machine of Global 500 enterprises. The fact that they receive the same or similar models and ages of retired PCs at the same time can greatly improve their whole processes from inspection to final testing. This is even more important for mobile PC refurbishment. When refurbishers purchased the used machines from collectors, individuals or public and private institutional users, they have very little information about system conditions in addition to different specifications and ages. When managing those varying PCs for refurbishment, both yield rate and recovery rate become lower and the overall operation costs become higher.

7. Legislation: Focus on Recycling

Around half of refurbishers think government policy focuses on recycling and discourages reuse market. Some collectors treat all the used machines as wastes and have no proper

treatment during transportation. Collectors, regardless of whether they are in public or private sector, normally have a long term partnerships with different recyclers. Recyclers have no standard prices for those used machines and recyclers in different region of the country offer different prices. When the prices offered by recyclers are higher than profit of reuse, most of the recyclers/refurbishers prefer to recycle instead of reuse.

8. Lifetime of Components and Reliability of Used Computer

When refurbishers were asked the approximate lifetime of secondary PCs they sell, no specific answers were given. The medium - sized refurbisher estimated around two to three years. Half of refurbishers said around one year depending on the reliability of original system. Half of refurbishers had no general ideas. However, most of them regarded the lifetime and reliability of used components and computers as major factors influencing secondary market. Furthermore, due to continuous price drop of new PCs, around half of refurbishers foresee the quality and reliability of new PCs would be worse than earlier generation PCs based on their experiences or knowledge. Other half of refurbishers feel it is hard to judge because of their experiences are limited to retired PCs of four to six year old. They do not see the major differences in terms of quality and reliability so far.

Furthermore, in certain circumstances, it is hard to get a good balance between cost and quality especially for small scale business with limited resources. When users concern the price of secondary PCs more, refurbishers may skip the long run testing for reliability or cancel warranty service. They think there were many uncertainties affecting the quality and reliability of secondary PCs. Customers might need some luck to get reliable or long lasting secondary PCs.

9. Threats to Producers and Recyclers

There are no consistent opinions about whether secondary PCs are threats to producers. Refurbishers/recyclers who do not sell new PCs consider secondary PCs are commodities belonging to different segments for different markets. Non-commercial refurbishers think secondary PCs are for users who have not used computers before and who do not plan to purchase new PCs anyway. However, some refurbishers who sell new PCs at the same time believe secondary PCs sometimes do replace new PC sales when there are significant price differences for customers. Another opinion from the medium - sized refurbisher is that producers do regard secondary PCs as threats in Taiwan and prefer him to sell refurbished PCs to emerging markets especially to markets where the producers do not have distribution channel or sales office yet.

Both non-commercial and commercial refurbishers receive feedback that refurbishment is a threat for recyclers even though the retired PCs would go to recycling plant eventually. It is the matter of time. Nevertheless, recyclers are still eager to collect those used machine for their daily operations.

10. Software Licensing

There are different opinions from refurbishers on software licensing. All of them feel customers cannot get used to open software as it was not taught at elementary schools. One of non-commercial refurbishers mentioned that there was a family received two free PCs through government projects. One PC was a secondary desktop PC with Windows XP and another one was a new 7" netbook PC with Linux operating system. The children didn't know how to operate a PC with Linux since computer classes in elementary school was all Windows

based. Moreover, though secondary PC users didn't need to have superior gaming machine, they did have demand on those communication tools such as MSN or SKYPE. Government policy was a key factor for refurbishers to promote open operating system. Microsoft has become one of the creators for rapid replacement of PC and led to global e-waste problems. Government has had too much focuses on the hardware development since the 1970. The whole infrastructure of software development needs to be managed and planned somehow.

With regard to Microsoft license, nearly one third refurbishers receives the deal about \$5 to \$10 US per copy of Microsoft Windows XP through Microsoft Refurbishment Program(MAR) or partnership with channel dealers. They feel the deal is acceptable. Another third of the interviewed refurbishers still consider Microsoft license as a main barrier. It is especially non-commercial refurbishers who have limited budget for whole refurbishing process. The remaining refurbishers provide no software to customers. They offer the genuine software for customers to purchase. The medium - sized refurbisher explains he does not provide software for his domestic or overseas customers. However, he has to install Microsoft OS first for the testing and uninstall it before shipment. He does not really appreciate Microsoft Refurbisher Program and think Microsoft should open Microsoft XP or 2000 operating system for corporate social responsibility. This approach could really help secondary PC market and ease e-waste burdens.

5.5 Summary of Drivers and Barriers

According to the stakeholder feedbacks, Table 5.1 provides the summaries of drivers and barriers perceived by three group stakeholders.

Table 5-1 Summary of Drivers and Barriers Perceived by Stakeholders

| Stakeholders | Drivers | Barriers |
|--------------------------|--|--|
| Government Bodies | <ul style="list-style-type: none"> - Bridge Digital Divide - Resource Conservation - Benefits to Low Income Families - Sustainable Consumption | <ul style="list-style-type: none"> - Safety, Functionality and Quality Concerns - Small prices differences between New and Used PC - Lack of Economies of Scale - Lack of Research and Development, Fragmented Industry and Groupings - Rapid Technological Development - Residual Value Hard to Define - High Operational Cost for Non-Commercial Market |

| | | |
|----------------------------|--|--|
| <p>Producers</p> | <ul style="list-style-type: none"> - Resource Conservation - Services for Commercial Customers | <ul style="list-style-type: none"> - Brand Image - High Operational Cost - Higher Toxic Substances of Secondary PCs - High Quality Standard and Hard to be Profitable - Safety, Functionality and Quality Concerns - Small prices differences between New and Used PC - Rapid Technological Development |
| <p>Refurbishers</p> | <ul style="list-style-type: none"> - Benefits to Low Income Families - Resource Conservation - Opportunities to New Market - Profitability | <ul style="list-style-type: none"> - Small prices differences between New and Used PC - High Operational Cost - Low Collection Rate(Lack of Available Fleet Machines- High Volumes of Used PCs with Identical Configurations) - Lack of Economies of Scale - Cost and Availability of Spare Parts - Unreliable Sources - Legislation - Lifetime of Components and Reliability of Used Computer - Threats to Producers and Recyclers - Software Licensing |

6 Analysis and Discussion

This chapter examines and analyses the drivers and barriers perceived by identified stakeholders. The reviews and discussions of drivers and barriers provide a background to a certain degree why they are key variables and what the associated opportunities or challenges can be. The information presented here is what the author learned from the interviewees listed in Table 3.1 or literature review, unless otherwise mentioned. Due to the request of anonymity from some of the interviewees, the specific sources of the information will not be written.

This chapter discusses drivers in the first section and barriers in the second section. Different stakeholders show the same concerns for particular drivers and barriers. To understand the interactions among different stakeholders, discussions start from the factors perceived by all the three stakeholder groups which meant followed by the factors recognised by less stakeholder groups. If a factor is perceived by a single group, the discussions begin with the factor perceived by government bodies, followed by that identified by producers and then by refurbishers.

6.1 Drivers

Figure 6.1 presents the drivers perceived by three stakeholder groups. Each factor shows the number of stakeholder groups which perceive the perspective factors as driver. The marks for groups in the line are I. Government bodies, II. Producers, and III. Refurbishers. Resource conservation is the driver commonly recognized by the groups of government bodies, producers and refurbishers.

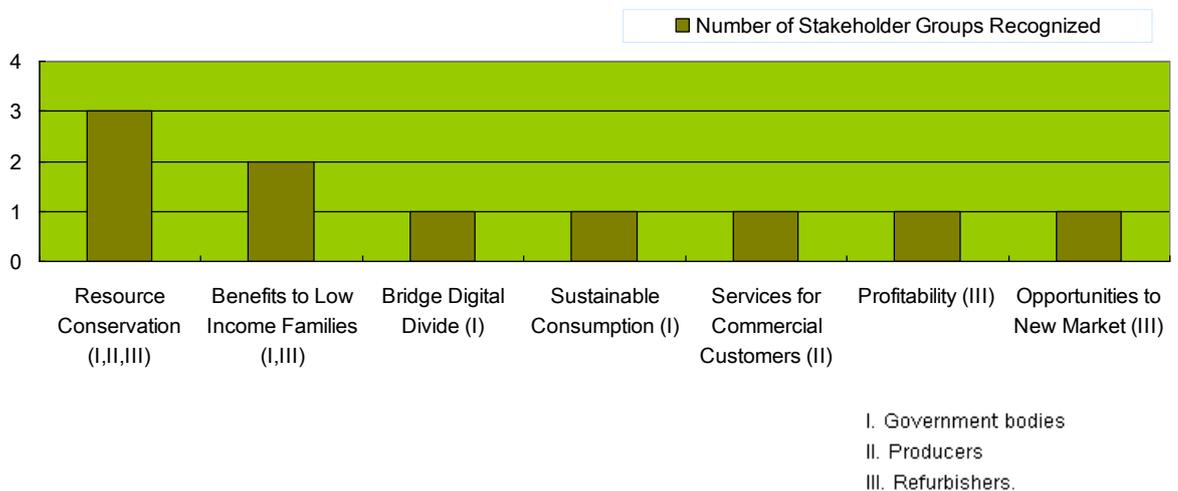


Figure 6-1 Drivers perceived by three stakeholder groups

6.1.1 Resource conservation

The interviewed government bodies recognize the importance of resource conservation. In 2002, Taiwan set its vision and strategies for national sustainable development in Taiwan Agenda 21 and highlighted the key issues of its scarce land, dense population, shortage of natural resources, frequent natural disasters, and unique international political status for pursuing the sustainable development (CEPD 2004).

For the Taiwanese market, producers are not actively involved in secondary PCs market except for the donation program coordinated by ASUSTek. For the European market, producers such as Dell offers asset recovery services to commercial customers while conserving the resources through partnership with refurbishers for refurbishing and reselling used and qualified computers to secondary users (Dell 2009a).

As for refurbishers, refurbishers have the capability to repair or refurbish used PC and components. They still prefer to do it and look for win-win situation to find customers in need. As mentioned by the chief executive of Charity Computer Aid International in UK, given the fact that manufacturing accounted for above 70 percent of the energy used in the whole life cycle of a PC, to recycle components of a computer which is still in working condition instead of reusing them is irresponsible (CRN 2009).

6.1.2 Benefits to low income families

In the mean time, secondary PCs allow more disadvantaged groups and budget customers able to get equal opportunities for accessing the internet and benefitting from its service. Benefits to low income families and budget customers are drivers for both government bodies and refurbishers. Some students and fresh graduates need low cost PCs. It is worthy to note that the price gaps between used and new computers are far more attractive for people in developing countries than those in rich nations. For instance, many U.S consumers make the choice of a new system of \$700 over a used system costing \$200. The \$500 difference probably won't be a burden and they may decide to choose the new systems. For consumers in poorer countries, the difference can direct them to the purchasing of the \$200 used system. It is also important to recognize that the purchase of a new computer is normally driven by the desire to more stylish design, new operating system or software or other functionalities rather than the defect of the machine. From economic, social and environmental point of views, secondary PCs can bring several benefits to the society (Allenby et al. 2008).

6.1.3 Bridge digital divide

Apart from resource conservation, bridging digital divide is one key direction Taiwanese government has been working on for its "e-Taiwan" policy. The World Summit on the Information Society (referred to as WSIS), led by the United Nation in 2003 in Geneva, aimed to strengthen national information and communication technology capabilities (Information Communication Technology, hereinafter referred to as ICT) by the resolution of international cooperation to promote national development. The World Summit on the Information Society was a meeting of world leaders at the highest level; the participating leaders aim to control the base information and communications technology in the digital revolution for the potential benefit of mankind. WSIS was a widely accepted process, engaging the participation of stakeholders such as governmental, intergovernmental and non-governmental organizations, private sector and civil society. Its objective was to "build the framework of an all-inclusive and equitable Information Society" and to find ways to use Information and Communication Technologies to achieve development goals. In such a society, everyone can create, access, use and share information and knowledge, so that individuals, communities and peoples can achieve their full potential, promote sustainable development and improve their quality of life. The action plan of the WSIS with a view translate the idea of reducing the number of digital divide of the international indicators into reality by setting a number of time-bound objectives (ITU 2003). According to the report of World Information Society 2007 issued by International Telecommunication Union (ITU), where indicated the development of information society status and trends of the "Digital Opportunity Index" (DOI), Taiwan was ranked as no.7 out of 181 countries in the world. It was improved from

no.10 in 2006 (RDEC 2009). However, this thesis research has the difficulties to obtain enough information to evaluate total market of non-commercial and commercial secondary PCs in Taiwan in recent years. Therefore, it is hard to evaluate the influences of secondary PCs to the growth of DOI.

6.1.4 Sustainable consumption

In 1998, the United Nations extended the guidelines of consumer protection to include sustainable consumption and released new guidelines for global consumer. UN defined sustainable consumption as "The use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life-cycle so as not to jeopardize the needs of future generations." (UN 1998). Consumer Protection Commission (CPC) referred to new guidelines of UN in 1998 and had six primary principles to transform consumer toward sustainable consumption (CPC 2010).

The Government's sustainable policy, in addition to resource recycling system and sustainable consumption, also provides another direction for waste reduction and product reuse. In response to World Summit on Sustainable Development Action Plan and Johannesburg Declaration on Sustainable Development, Executive Yuan's Council for Sustainable Development draw up the plan in the fifth task group to guide the establishment of second-hand market to encourage the transaction of second-hand products and reduce the waste amounts (EPA 2004). However, according to the discussions with Department of Commerce, Ministry of Economic Affairs, the second-hand products in the demonstration projects of second-hand market were still limited to books, furniture, clothes, bags or other groceries¹¹.

Despite of perceived benefits for PC reuse, there are no consensuses among government bodies as to who should take the lead in smoothening the process of integrating secondary PCs into a sustainable market mechanism. When Taiwanese economic environment is tended to encourage the production and consumption, incentives such as low VAT, business tax and depreciation rules¹², reuse shall be in much higher priority for government to conserve the resource and reduce the environmental burden.

6.1.5 Service for commercial customers

Dell recognizes environmental consideration is one of crucial criteria for commercial customers to evaluate their IT purchasing decisions. As a producer having a large share of commercial market, in order to fulfil customer demand, they invested in service structures and built the partnership with refurbishers or recyclers to handle those end – of - life IT products in a professional and safe manner. Both HP and Dell released the guidelines for reuse or recycle to their refurbishers or recyclers for safe disposal of IT products in compliance with environmental and regulatory standards¹³. In Europe, those refurbished PCs are sold through

¹¹ See <http://gcis.nat.gov.tw/usedgoods/store.html>

¹² See <http://www.mof.gov.tw/ct.asp?xItem=26131&CtNode=735&mp=1>

¹³ See <http://www.hp.com/hpinfo/globalcitizenship/environment/recycle/finalreustds.pdf> and <http://i.dell.com/sites/content/corporate/environment/en/Documents/Electronic%20Disposition%20Policy%20May%202009.pdf>

refurbishers or broker channels. Producers also can retain their business customers by providing better services for environmentally responsible disposal, safe data destruction, and potential financial return incentives. The operational cost and end – of - life disposal cost are two economic forms related to IT procurement. Gartner illustrated a disposal cost for business customers in USA and advised companies to carefully handle IT asset disposal process (Escherich et.al 2008). Appendix A-3 provides reference information to show activities associated with IT disposal and reveals brokered sales or auction and outsourcing are most cost effective for US business customers. Due to business confidentiality for producers, this research is unable to obtain the real value of financial structures dealing with end of life PC at business customer site in Europe. For a better understanding, table 6.1 outlines the options and financial structures of IT disposal Dell offered for its business customer in Sweden.

Table 6-1 Dell Recycling Options and Financial Structures for Commercial Customers in Sweden

| Options | Producers- Recycler Partner | Producers- Refurbisher Partner |
|---|--|---|
| Recycling | Transportation cost | |
| Asset Recovery Service and Recycling | HDD data destruction cost (on-site and off-site) | |
| Asset Recovery Service and Refurbishment/Resell | | HDD data destruction cost (on-site and off-site)+Resale Value |

However, as mentioned in earlier section 5.2.2, HP environmental manager points out most of business customers go through brokers offering higher prices for their retired PC. The studies of broker activities for domestic reuse, recycle or export are important but out of scope for this research. This issue needs to be observed and discussed in future researches.

6.1.6 Profitability

Profitability and opportunities for new markets are two additional drivers perceived by refurbishers. Most of the refurbishers consider that profitability of refurbished PCs is higher than new PCs. This is especially the case when they get used but functional systems or components at zero or very little cost: their profit can be doubled or tripled. However, due to perceived barriers discussed later in this chapter, the volume of refurbished PC is still limited. The overall incomes generated from the sale of refurbished PCs have been not significant for most of refurbishers. The profit per unit can be around 30% to 50% depending on the cost and quality of used PC they purchased. It is similar to the global market situations. The main reason behind can be recycling is not an independently profitable business model. Companies involved in secondary PC business always treat recycling as the last option. The value of a PC recycling is around \$6 to \$8, significantly lower than the value of a basic reusable PC. The value of a reusable secondary PC depends on its condition, specifications, brand, formfactor and volume. The estimated profit margin on a refurbished PC is approximately \$10 to \$50 for a three-year-old machine. The actual recycling of used EE products is time intensive in terms of labour, power in part: The equipment must be separated into its component parts, including the plastic housing, copper wires, metals (for example, gold, silver and aluminium), and circuit boards, as well as parts that can be easily reused or resold, such as hard drives and CD-ROM drives. In addition, in order to obtain useful products, metal and plastic scraps must be further processed to obtain shredded plastic, aluminium, copper, gold and other recyclable materials, such treatment often requires million of dollars of machinery. Finally, more recycling and disposal costs will incur to handle the toxic elements (such as mercury-

containing components). In contrast, selling used PCs or components for export are simple and profitable (Escherich & Charles 2009).

However, refurbishers also mention that when our governmental policy intends to encourage the recycling, it would harm the activities of reuse somehow. If collectors, refurbishers or recyclers can get similar or higher profit for recycling, the reuse of computer cannot be continued in commercial basis.

6.1.7 Opportunities to new market

This kind of situation is mainly applicable for foreigner market. As the highlights in Microsoft whitepaper of secondary PC ecosystem (Microsoft 2008) and inputs from the medium size refurbisher in Taiwan, secondary PCs can actually create new markets for hardware, software and services that most of companies didn't expand to there yet.

6.2 Barriers

Figure 6.2 presents the barriers perceived by the three stakeholder groups. Each factor shows the number of stakeholder groups who perceive the respective factors as barriers. There are five common barriers perceived by three groups. The sixth barrier relates to economies of scales is barriers recognized by producers and refurbishers. The seventh barrier about safety, functionality and quality is one of key concerns by government bodies and producers.

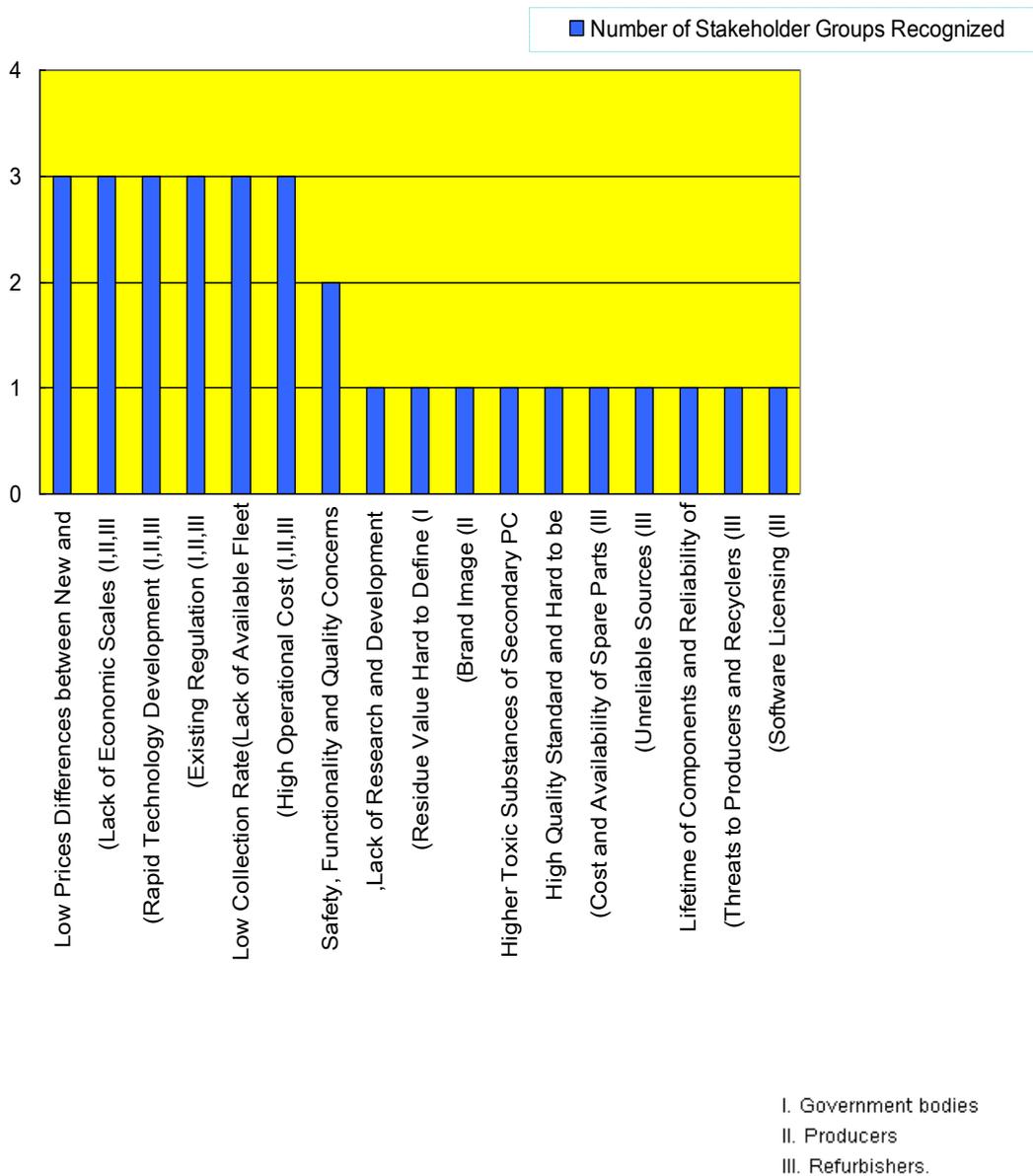


Figure 6-2 Barriers perceived by three stakeholder groups

6.2.1 Small prices differences between new and used PC

In 2009, Netbook played a key role in boosting the overall PC shipment but also decreased the average sales price (ASP) sharply. Two main reasons for the drop of ASP by almost 19% ASP are low average sales price of netbook - around \$350 US per unit- and the corresponding price pressure given to traditional Mobile and Desktop PCs. Consequently, the ASP of Mobile and Desktop PC ASP also dropped. On the other hand, Mobile PC and netbook transformed the consumer market from family base to personal base. Together with Windows 7 and continuous reduction of new PCs, large amount of PC replacement can be expected in 2010 and 2011. Figure 6.3 presents the ASP trend of PCs from 2004 to 2011. In the past six years, ASP of Desktop PC dropped by around 30% and Mobile PC dropped by 45% (TRI 2009).

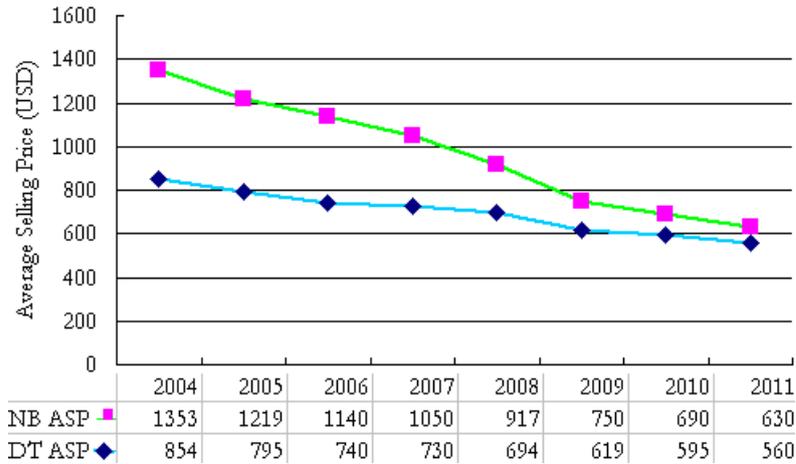


Figure 6-3 PC ASP trend 2004~2011

Source: TRI 2009

The trend toward falling prices of new computers does not seem to stop. It is neither feasible nor practical to incorporate remanufacturing into the PC lifecycle at present time. The price drop, coupled with the increase in labour costs can adversely affect the profit margin of used PCs for refurbishers and resellers as well. This highlights the need to look for the most economically viable solution for the preparation for reuse and then increase the PC environmental effectiveness. Nevertheless, reselling in secondary markets had been identified as a possible option to prolong PC lifetime (Hickey & Patrick 2008). More details in potential paths for improving the situation would be presented in recommendation section of final chapter.

6.2.2 Rapid technological development

Rapid technological development in PC industry is a common barrier for producers, government bodies and refurbishers. Refurbished PCs become unattractive to users especially in mature market when users constantly receive all kinds of information from media or shops.

In general, for viable remanufacturing and refurbishing, technology must be stable over more than one life cycle (ex.3 years for a PC). In PC industry, the constant evolution and improvement in terms of performance, storage capacity, and functionality has made PC remanufacturing hard to be practiced in a large scale. According to Moore’s law, the observation made by Gordon Moore in the 1960s, a processor’s speed would double every 18 months. Since then, the development has been on pace. Moreover, one of the characteristics of PCs different from other electronic products is that they are composed of standard components developed by sub-suppliers and sold by retailers. The evolution of processors, software and other main components such as graphic cards, hard disk drives and memory chips has continued to push industry forward and stimulate various types of new PC product designs. This has creates a very dynamic sector as a result of huge business potential for many different sectors. Rapid technological changes let PC design process almost impossible to incorporate consideration of lifetime extension. The evolution of different components and functions of PCs has resulted in the changes of physical design of the casing and components and as a consequence old components are not always compatible with those in a new system. Furthermore, low end specification system does not retain high value. Even low end PCs are

made with a diverse range of complex subassemblies which are not easily interchangeable. All the issues mentioned above make the preparation and processing for reuse hard to be profitable (Hickey & Patrick 2008).

By looking at 320GB hard disk size or 4GB memory as generic specifications in a mobile PC, PC hardware performance has become more than adequate to handle software and operational demand even for five or ten years later (Fiering 2009). Moreover, the internet applications have been the main driving forces for the PC industry. Over the next ten years two additional driving forces boosting the PC industry will be the consumer electronic devices which include computing platforms and mobile devices such as smart phones and multifunctional cell phones (eTTForecasts 2010). Technology adopters or fashion followers would always prefer the latest and newest design. To capture the retired products from this quick turn cycle will be an important issue.

6.2.3 Legislation

For Secondary PCs or secondary EE products in general, this research discusses the legislation from following two aspects.

1. Waste Disposal Act in Taiwan: the main issue for PC producers in Taiwan is the recycling fee collected at the time when products are put on the market but the recycling activities have not been significant enough to use most of accumulated funds. Another issue is about the high administration cost under this scheme. It accounts for 25% of the total RMF fund. Refurbishers and recyclers also have the same concern about low recycling rate especially for mobile PCs. On the other hand, when governments tried to encourage the recycling activities in Taiwan through the current scheme, the subsidy and little requirement made the entry level too low and got too many players involved. Refurbishers or recyclers are hardly able to sustain their businesses. However, the background of the establishment of RMF is the consideration on some social aspects. Before the Waste Disposal Act, there were a certain number of collectors in Taiwan to deal with different kinds of waste recycling. They did collection and recycling for living. In order not to affect their activities for livelihood too much, government got involved to allocate recycling funds and not to leave all the authorities or responsibilities to producers. After the implementation of Waste Disposal Act for 10 years, in 2008, EPA requested CIER to conduct the research for planning and optimization for producers' waste electrical and electronic equipment recycling schemes. It was to evaluate the advantages and disadvantages to let producers form their own recycling schemes to take back their products and gather the inputs from producers and recyclers (CIER 2008). However, because of the lack of consensus among producers, no changes have been made so far. EPA also recognized the main issue to tackle is the incentive to consumers. EPA does not consider the deposit-refund concept proposed for future e-waste regulation and management systems in the U.S. (Allenby et al. 2008) will be practical in Taiwan. It may discourage the new product sales for which producers will have serious concerns.

According to Gartner analysis, the increasing number of laws based on extended producer responsibility such as WEEE inhibits small players in secondary PC market. They may feel difficult to compete with large vendors such as HP, Dell and Lenovo (Escherich& Smulders 2008). However, it also depends on the government regulations to recyclers and commercial customers. Depending on how e-waste scheme would be implemented, a take-back recycling system may either stimulate or inhibit the re-use market (Allenby et al. 2008).

2. Sustainable Policy in Taiwan:

There is a lack of central guideline regarding reuse and recycling in sustainable development policy. Sustainable economy is one of policy elements of the Taiwan Agenda 21. However, it only drew up plans for recycling rather than reuse (CEPD 2004). It is most likely impossible for Taiwan to change the economic structure and pattern of productions and consumptions in a short term period. However, it is crucial to raise customer awareness and design a sustainable mechanism to encourage product reuse and then recycle. EPA explains that they had certain agreements with recyclers to use the recycled materials for domestic demand. Yet considering the scarce land and limited natural resources in Taiwan, the circular economy currently supported by China and United Kingdom government shall be taken into consideration. Preparation for reuse needs to be emphasised and well communicated. After all, the environmental impacts of reuse are much less than of recycling (Allenby et al. 2008). The Chinese Government issued its circular economy law in 2008¹⁴. In chapter 4, it states reuse and recycling.

“Article 39: Any recycled electric apparatus or electronic product to be sold after repair must meet the standards for reutilized products and be labeled it as a reutilized product at an eye-catching place.”

“Article 40: The state supports enterprises to reproduce the parts and components of motor vehicles, engineering equipment, machine tools, etc. and to renew tyres. Any reproduced or renewed product to be sold shall satisfy the prescribed quality standards of the state and be labeled as a reproduced or renewed product at an eye-catching place.”

Article 39 and Article 40 describe the rules for reutilized products. It can be the references for the Taiwanese government to define the principles for secondary products.

6.2.4 Low collection rate (lack of available fleet machines - high volume of used PCs with identical configurations)

Figure 6.4 presents the amount of sales and recycling for desktop PCs and mobile PCs.

¹⁴ See <http://www.chinaenvironmentallaw.com/wp-content/uploads/2008/09/circular-economy-law-cn-en-final.pdf>

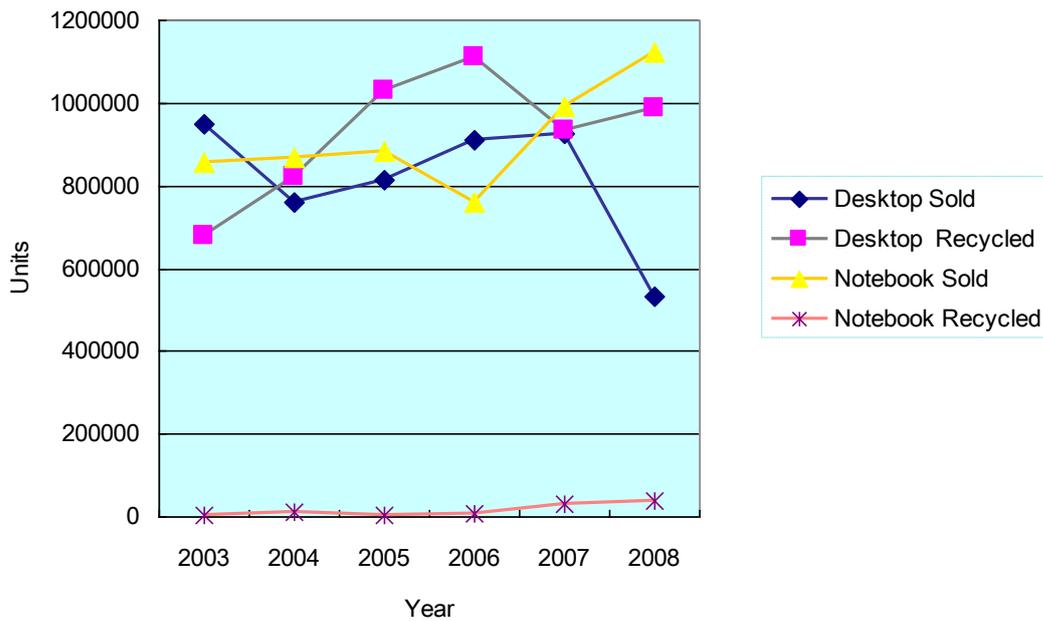


Figure 6-4 PC recycling historical record 2003~2008

Source: ITRI 2007, Triple-E 2009

It shows that mobile PCs has very low recycling rate. Producers, EPA and refurbishers all recognize this issue. A few refurbishers mention certain volumes of used notebooks are exported to China. Other refurbishers, producers and EPA think that most of notebooks are still stored by privates. Commercial machines have higher likelihood to be refurbished, recycled or exported. All the three parties feel there have not been strong incentives for consumers to recycle or resell their mobile PCs while they were all bought at much higher prices many years ago, still workable or waiting to be repaired. It is a general issue across countries or regions especially in mature markets. In developing countries, some collectors will pay high price to collect the used PCs from households. However, no matter what kind of regulations are enforced, in countries or regions such as USA, Western Europe, Japan, Australia and Taiwan, most of consumers still feel reluctant to recycle or resell their used PCs. Since consumers are the ultimate actor to decide how they treat their unwanted PCs, consumer awareness and willingness to manage their e-waste properly are important factors influencing the e-waste problems and the reverse supply chains. Electronic products are usually perceived to retain a residual value, even if they are outdated or no longer functioning. This value sometimes makes consumers just do not want to simply ‘throw them away’. Consumers have no idea as to how to handle with the products. It is very common for computers and other e-waste with high perceived value that people do not dispose them in the bin but will keep the products in storage or give them away to another user (Encycle 2009).

HP manager highlights that for an efficient recycling scheme, the characteristics of IT products must be recognized. Unlike the kitchen white goods which households would buy a new one and get rid of the old one immediately, IT products are in much smaller sizes and users paid thousands of dollars years ago. It is also shown in the report that small EEE has lower collection rate comparing with large EEE in some countries (Davis et al. 2001).

In the world's first international e-waste academy, the experts highlight that standardized processes and policies for governing the re-use and recycling of electronic products need to be set up globally to stop and reverse the growing problem of illegal and toxic e-waste processing in developing countries. An old computer with Pentium II process and open source operating system can perform faster than some of new models on shelves. It is also vitally crucial to get unwanted device in the re-use loop before getting too old or damaging to re-use (UNU 2009). In the case of cell phone re-use practices, for a refurbisher, the main challenges are to choose return incentives and collection systems to greatest extent between resale values and reverse logistic costs (Blass& Geyer 2009).

The sources of available fleet machines-high volume of used PCs with identical configurations for secondary PCs are not abundant in Taiwan. According to the survey made by ASUSTek donation program, in accordance with the requirements of government agencies, the service life of IT equipment is normally four years. However, still around 20% of IT equipment in service life for five or six years. The vast majority of the respondents to the survey mention that even though government agencies have certain degree of retirement age for PCs, it is still impractical to discard all the PCs whenever they reach their service life. Most of governmental agencies would determine the conditions of used PCs and decide whether to retain or replace of old computers. Moreover, the number of discarded PCs every year is uncertain.

The uncertainty of used PCs from government agencies or private sectors and economic recessions has led to a short supply of reliable sources for secondary PCs. In the global market context, it is also the fact that recession always means a shortage of available cash (Escherich&Smulders 2009). However, from environmental point of views, prolonging duration of PC usage by primary users is still better option than let PCs enter its secondary life or recycle it.

6.2.5 High operational cost

Both in non-commercial and commercial market, the service costs are unneglectable. Because of the different characteristics between non-commercial and commercial secondary PCs market, most of the refurbishers provide one year warranty for donated PC but 30 days to 3 months warranty for commercial sales. The same strategy is taken by producers who sell remanufactured PCs in their outlet. They only offer limited warranty for remanufactured PCs¹⁵. One or two year warranty is provided just for new products. Can it be assumed if there is an efficient remanufacturing business operated by producers, the service and other operational cost can be reduced significantly? So far, there is no study indicating that PC producers could make profit in the remanufacturing industry business. In China, the government promotes circular economy and encourages remanufacturing industry. However, so far, it has been limited to the categories such as toner or ink cartridges.

Although remanufacturing is regarded as one of the best environmental options to deal with end – of – life products, it is crucial to understand under what circumstances it is an appropriate treatment choice in terms of environmental and economic viability. For the PC industry, the factors affecting their choice of their products end – of – life treatment are dynamic, including issues such as global economics, technology, policy, customer preferences and educations. Those factors are in constant flux and cause boundary shifts between viable and non-viable practices (Hickey & Patrick 2008).). A study on the practices of cell phone re-

¹⁵ See <http://www.dfssdirectsales.com/StoreCatalog/ctf641/sitecontent/LimitedWarranty/LimitedWarranty>

use in Europe and USA indicates that when re-use yield rates are higher than 50%, cell phone refurbishers are able to afford the cost of collections and incentives to consumers. In addition, most cell phones for re-use are only tested and cleaned without disassembly or components replacement (Blass& Geyer 2009).

Furthermore, the whole refurbishing processes are labour intensive. In the case of forward manufacturing, component vendors have particular testing programs for each new component in a standard production line. Manufacturers would just do a random testing such as one out of 100 pieces before assembly. To assemble a new PC, this way takes around 12 minutes. In the contrary, the inspection and testing stages for refurbishing requires two to three hours. For refurbishers, it is not possible to do a complete testing based on the current operations and limited technical resources provided by producers.

As for producers and their partners for recycling or refurbishing, partners must follow treatment requirements released by producers. According to Dell Electronics Disposition Policy 2009 (Dell 2009b), the requirements for equipment refurbishments are

1. Meet standard minimum technology specifications
2. Ensure all equipment fully tested and functional when marketed or distributed as a refurbished product.
3. Responsibly handle the data destruction on refurbished equipment based on Dell's data destruction standard.

To ensure the safety and quality of refurbished PC and also protect its brand image, Dell released its guideline to their environmental partners for responsible refurbishments. The total operational cost comparing to other small or medium size refurbishers will be higher. Therefore, it is most likely not possible to have profit sharing for a regular secondary PC sale among three parties-customers, producers, and refurbishers in those service or regulated countries. Figure 6.5 shows the labour cost that Taiwan ranked as the sixed lowest country of hourly compensation cost in manufacturing. The operational cost for PC refurbishment and reverse logistic in mature country will be much more significant.

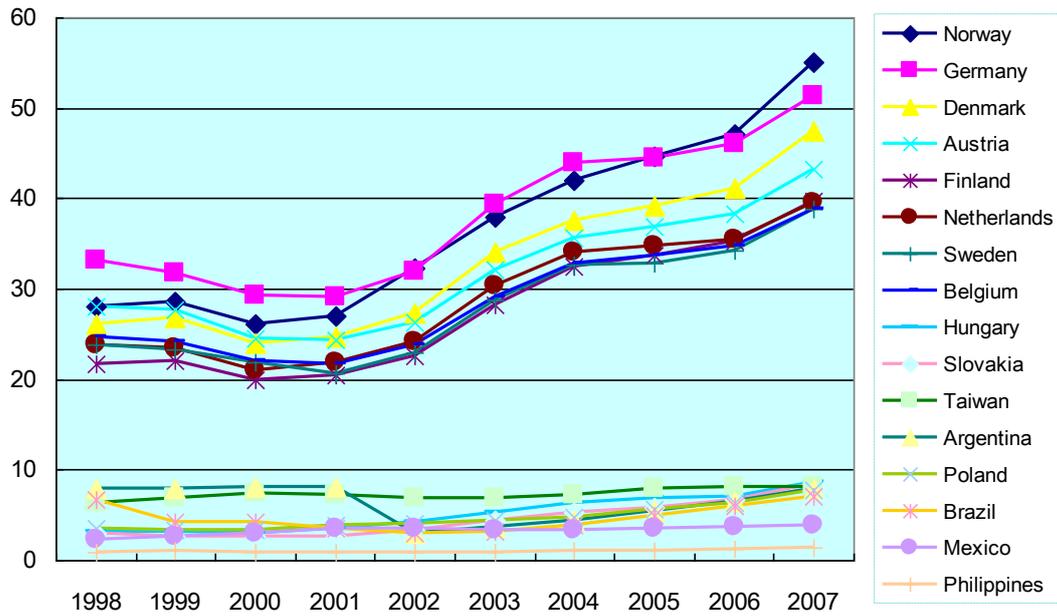


Figure 6-5 Hourly compensation costs of all employees and production workers in manufacturing, 2007

Source: BLS 2007¹⁶

In order to decrease the overall cost (collection, operation and service) and increase yield rate for the re-use of PCs, an effective reverse supply chain and cost-benefit analysis shall be explored. There are many factors to be considered, such as: How many facilities should be established to carry out recovery and re-use activities? Where should each facility be located? Which recovery and re-use activity should be dedicated to each facility? How large should each facility be? How should the physical flows be arranged among the facilities for recovery and re-use? The logistic type, demand and supply modelling, static and dynamic models (demand, supply and costs change drastically over time and the network can be modified to accommodate these changes), logistic structure and flow assumptions need to be evaluated as well (Akçali& Üster 2009).

6.2.6 Lack of economies of scale

Economy of scale, in microeconomics, is the cost advantage that businesses can benefit from expansion. It is assumed that producers' average cost per unit is reduced as scales were increased. Economy of scale can be utilized by any firm expanding the scale of operation such as purchasing, managerial, financial, and marketing activities. From long run perspectives, these factors can help to reduce the average costs of production (Sheffrin 2003).

Most of small scale refurbishers suffer from high operational cost and low customer demand due to lack of the economy of scale. If they cannot expand their business scales, they face many difficulties in lowering the overall cost. It can be said that a medium- sized or a large project usually gain higher profit than a small project due to lower transaction costs and

¹⁶ Download full index <http://www.bls.gov/ilc/flshcaeinnaics.htm>

economy of scale (Assenza 2008). In the mean time, when the demand and supply of secondary PCs in Taiwan is uncertain, it is hard to plan for expansion to make refurbishment business profitable. This is true not only for refurbishing but also for recycling. If a refurbisher has his/her own recycling business, due to the high investments needed to establish a standard recycling facility, this business can only have a market potential when a large quantity can be accessed from a entire region and/or through favourable trade routes(UNEP&UNU 2009). When the market potential is not promising and there exist too many similar players in the market, it is difficult for both recycling and refurbishing business to sustain in Taiwan. The Taiwanese government also gets constant challenges if they should open the market for international EE recycling and refurbishment.

6.2.7 Safety, functionality and quality concerns

The partnership between producers and qualified refurbishers does not exist in every country. It mainly depends on local laws on e-waste and market size of a country. If the retired machines are not refurbished through complete processes such as fully functional testing as well as replacements with qualified components, they may have issues related to safety, function and quality. A refurbished system without proper ElectroMagnetic Interference (EMI) and Electrostatic Discharge (ESD) solution may have problems with interference on the communication and higher possibility for the systems to be hanged up. The impacts of EMI issue on city users will be higher than rural area users. Airport area is a sensitive area as well. Those self-assembled desktop PCs generate the same risk when they are not complying with an appropriate safety standard. This issue should be discussed at the national level along with proper risk assessments. When it comes to the issues of mobile PC reuse, the battery is the most critical item for safety.

In general, the lifetime of a mobile PC battery is around three years. (500 times fully charged and discharged). Battery lifetime refers to the circles that battery charge and discharge can be repeated until the battery is not able to accumulate electrical power anymore. Battery lifetime largely depends on working temperature of the battery and rate of discharging. In principle, the higher working temperature and faster discharging speed will reduce battery lifetime. The battery temperature will be influenced by temperature of ambient air, heat generated by mobile PC and design of heat emission. The rate of discharge depends on computer running program and power management setting. For example, mobile PC constantly running programs for calculation, gaming or DVD player will have much shorter battery lifetime than other laptops mainly operating the office work (HP 2010).

Most of PC producers have experienced the cases of million of mobile PC battery recalled due to the risk of lithium-ion battery overheating¹⁷. The problems can be caused by cell issues or the design of gauge ic. Gauge ic controls the capacity, learning and protection of battery. Two main producers of gauge ic are Texas Instruments (TI) and Maxim for branded battery such as Sanyo or Sony. Some third party suppliers may have issues on the design, source selection and testing criteria. To meet customer demand, if refurbishers choose to replace the battery with cheap but unreliable sources from the third party suppliers, the user may encounter safety risks.

¹⁷ See <http://www.cpsc.gov/cpscpub/prerel/prhtml09/09035.html>

6.2.8 Lack of research, development and fragmented industry and groupings

With regard to lack of research, development and fragmented industry and groupings, the practice of mobile phone can be as a reference in the future for the status of secondary PCs. In the mean time, it is also global challenge to trace the flows of electric electronic wastes or secondary product. Radio-frequency identification (RFID) can be one approach. However, the applicability of the RFID for small appliance is still on doubt.

On the other hand, the stakeholder interview has not been a common approach for policy analysis in Taiwan. From 2004 to 2009, there are total 12 research reports related to Waste Disposal Act for IT products and two research reports about secondary PC donation¹⁸. However, none of them included the interviews of refurbishers or recyclers and the studies of recycling or refurbishing activities within recyclers. For the secondary PC donation, some key barriers such as high transportation cost still exist after six year practices. The government project or study should be built based on sustainable mechanism. It would be more beneficial and effective if they can be replicated by private organizations. It can also save a lot of unnecessary cost and resources either on project planning or research.

Concerning the difficulties of defining residual value, it has been disputed if Waste Act Disposal should regulate the activities associated with reuse instead of leaving it in the hands of free market. Reuse of resources and waste prevention are still the primary principles for EPA. EPA should coordinate other government bodies to identify the problems and tackle them in a collaborative way, so that a free market for used EE products can be able to operate smoothly.

6.2.9 Brand image

For PC market in Taiwan or consumer markets in general, producers have small involvement in the secondary PC business. Previous chapter describes their main concerns. This section provides details and backgrounds to see why they may be important to producers.

Brand image is one of major concerns for producers to participate in secondary PC market. The value of brand images is when customers have willingness to spend money or pay extra to buy this brand product. It means the brand has its value. Brand value is normally associated with product marketing, design, quality, services and nowadays, corporate social responsibility. To provide the same or similar quality and service on secondary PCs as new PCs in order not to ruin company image, producers need to have huge investment for this reverse supply chain. Moreover, the complexity of this market and non-transparent activities of primary users as well as refurbishers/recyclers/resellers give no incentives for producers to claim they are involved in the business of secondary PCs. One refurbisher mentions one producer would not repair their netbook models when customer calls for the service. They swap the whole system with new ones during the warranty period. Afterwards, they collect those defective systems and resell to refurbishers/recyclers. The refurbisher is also informed by producer to remove the logo before refurbishing or recycling. When a netbook becomes so cheap and not worthy for repair, netbook seems to belong a category of disposable product. Another case is that producers would bring in their corporate customers into selected refurbishers to collect, refurbish and resell those retired PCs. This kind of partnership is informal without the profit sharing.

¹⁸ http://epq.epa.gov.tw/search/search_result_simple.aspx

6.2.10 Higher toxic substance

Higher toxic substance in secondary PCs is another additional factor that HP prefers not to reuse but recycle for end - of - life equipment. The European Union Directive 2002/95/EC regulates the use of certain hazardous substances in electrical and electronic equipment. This Directive is often referred to as Restriction of Hazardous Substances Directive (RoHS) adopted in February 2003 and came into effect on July 1, 2006. ROHS Directive prohibits six hazardous substances in electronic products sold in all the European Community. The best known item is lead and other five substances are mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) flame retardants in the shell and the circuit board (ROHS 2006). However, this concern should be discussed in an international level. Both component or system reuse and recycle may face with the similar situation i.e. the old PCs they handled contain those substances. Some recycling for plastic components will encounter the same issue. There are increasing demand to use post-consumer plastics in new product design. Electronic Product Environmental Assessment Tool (EPEAT) offered by the Green Electronics Council, USA and Greenpeace Guide to Greener Electronics have this criterion in their new examination requirements^{19,20}. One possible and common approach can be the sorting by manufacturing code and put certain restrictions in the reverse supply chain for EE products produced before 2007.

Five additional barriers perceived by refurbishers as follows,

6.2.11 Cost and availability of spare parts

There are less common parts for mobile PCs. The unique items of mobile PCs are usually associated with higher cost and lower availability. Component manufacturers have their mass production plans for each component. When the components are no longer produced, it became almost impossible to resume the production without paying huge amount of money. On the other hand, PC producers would work with component manufacturers to secure the demand of spare parts for service purposes. When a PC product is going to be phased out, all unique components will be produced and stored in warehouse of producers or manufacturers. The administrative costs and warehouse costs in supplier sites have made unique components more expensive year after year.

This issue has been worsening for private consumer electronics. Manufacturers have tried to stimulate consumer market and have designed a wide range of product with different designs. Consumers are also attracted to purchase the products with cheaper price, higher specification, and better appearance. It means less and less common parts among product groups or generations. This kind of trend discourages refurbishing and repairing activities but encourages recycling or disposal behaviour.

When refurbishers are asked to have comments about PC designs for reuse, most of them have no specific comments. Most of laptop designs have considered the serviceability and upgradability to remove hard drive disk or memory module through a few easy steps. Two refurbishers mention the priority should be given to the common design of battery and adapter. They pointed out that customers will appreciate most if any producers claim their PCs have the same type of adapter or battery. For mobile industry, European Commission had requested industries for a voluntary commitment to provide compatible mobile chargers for users. The incompatibility of mobile phone chargers is a major inconvenience for users

¹⁹ See <http://www.epeat.net/Docs/Summary%20of%20EPEAT%20Criteria.pdf>

²⁰ See <http://www.greenpeace.org/international/PageFiles/24473/improved-criteria-explained.pdf>

and led to unnecessary resource consumption and waste. According to this harmonisation of a charging capability of common charger for mobile phones, Micro-USB will be universal EU phone charger from 2012(EC 2009). Moreover, one refurbisher/ recycler replies that it is not realistic to consider certain designs easy for reuse or recycle when consumers will not have intention to purchase products with such design profile. The standardization and minimization of screw types can be a basic item to define.

6.2.12 Unreliable sources

The quality of sources is a key factor affecting the recovery rate and overall refurbishing performance. According to the inputs from informants, the recovery rate has 65% to 90% for refurbishments of two – to three – year – old retired PCs from commercial customers. However, only around 20% to 40% recovery rate can be achieved for refurbishments of other PCs which are older and obtained from various sources. The quality, timing and quantity of returned PCs are important issues for reverse logistic. An efficient acquisition and reverse distribution system is critical for tracking, collection and returned used PCs to refurbishing and remanufacturing centre. It is generally successful to incorporate certain types of business models when designing reverse logistics. However, for home market, successful practice is lacking at present and has made acquisition an extremely tough task (Hickey & Patrick 2008).

6.2.13 Lifetime and reliability of used components and computers

Figure 6.6 illustrates an overview to understand potential factors influencing the quality of PCs for primary users and secondary users.

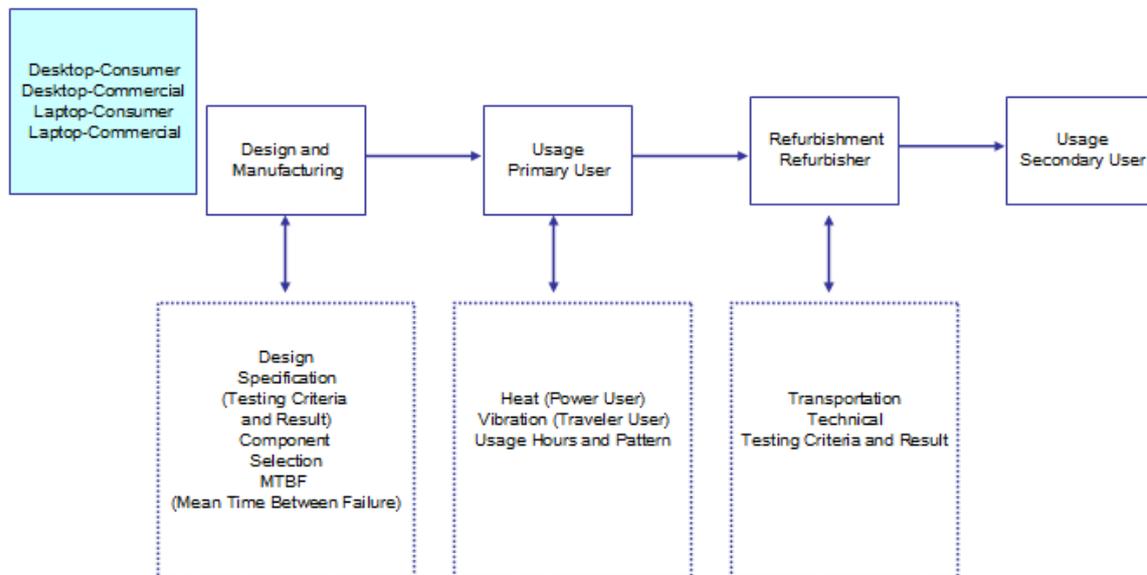


Figure 6-6 Potential factors influencing the quality of PCs for primary users and secondary users

Based on the reviews of secondary data for lifetime of PC (Triple-E Institute 2009), there are different approaches for the simulation so that the results vary from one to another. Due to uncertain scenarios in above stages and limited information from suppliers or refurbishers on criteria or specification, it is not possible to provide a justified answer with regard to the

lifetime of PC. The raw data from component suppliers with the consideration of user feedback can be reliable. However, owing to the confidentiality of company information and the complexity of user research, it is beyond the scope of this research to analyse the reliability of components further. In this section, based on the inputs from refurbishers and secondary data review, a few conclusions can be drawn in terms of aspects of component and product design,

- Harddisk drive, motherboard and power supply have shorter lifetime than other components.
- The retired PC from commercial non-power and less traveler users have higher possibility to reach longer secondary lifetime.
- Designs to protect harddisk, battery and improvement on heat emission are beneficial for computer reuse.
- The cleaning processes to remove the dust are crucial steps for the refurbishment of Desktop PC.
- Owing to the mobility of laptop, the replacement of hard disk drive or some unique parts such as motherboard and hinges are recommended.

According to earlier statistics (Escherich&Smulders 2008), one in three secondary PCs was a notebook. Apart from its mobility for individuals, notebook has its advantages such as being battery-driven instead of depending on electricity or using a wireless without the needs of landline connections. However, the problem for notebook is its shorter life cycle compare to desktop and replacement of notebooks driven by its high failure rate. This is different from the replacements of desktop PC driven by new operating systems, application software or latest graphics or processors. The annual failure rate for notebooks by the third year is estimated up to one in four. By the fourth year, the failure rate would be closed to one in three. The second life of a notebook probably would be ended after one or at most, two years. After that, it has to be disposed of (Fiering 2009). Gartner estimated that by 2012, emerging markets will need to dispose 30million secondary PCs annually (Escherich&Smulders 2009). However, there are different factors affecting the second life of a used PC. In general, the notebooks used by day-extender and the desktop operated by fixed-function or task-based worker can have longer lifetime.

6.2.14 Threats to producers and recyclers

According to the experiences of non-commercial and commercial refurbishers, some recycling businesses are controlled by gangland in Taiwan. The more PCs reused mean the less PCs recycled for them. On the other side, some producers such as HP own the share of recycling plant in Europe named ERP-European Recycling Platform²¹. They prefer recycling more than reuse. In regards to Taiwanese market, the secondary PC markets are not significant. Other producers such as Acer do not perceive secondary PCs as a threat. Dell Sweden manager also thought new PCs and used PCs belong to different markets. Secondary PCs have their own market that will not replace new PC market. This kind of situation is probably applicable for foreigner market instead of domestic market. As the highlights in Microsoft whitepaper of secondary PC ecosystem (Microsoft 2008) and inputs from the medium size refurbisher in

²¹ European Recycling Platform (ERP) was created in 2002 as the first ever pan-European take back scheme to effectively implement the European Union's [Waste Electronic and Electrical Equipment](#) (WEEE) Directive..

Taiwan, secondary PCs can actually create new markets for hardware, software and services that most of companies didn't expand to there yet. In reality, it is still questionable and hard to justify without a large scale stakeholder and consumer survey. Different countries may have different perspectives as well.

6.2.15 Software Licensing

There are two issues identified through interviews in Taiwan in terms of software licensing. The first one is low acceptance of open source operating system. Another one is the license fee of Microsoft operating system. Microsoft operating systems are still dominant in public sectors, private sectors and at private households. One refurbisher suggests to start from primary schools and government bodies to enhance the use of open source operating system (OS)²². The governmental bidding projects also can set the maximum price for OS to prevent the monopoly issue. Government started to implement some projects such as the trial run of open document and the city of Linux.

In recent years, the quick development of open OS in international society has stimulated a total package service of open OS via user friendly interface design. The experts working in open OS field understand that many people need computers mainly to access information and make communications. Ubuntu is one of the most popular total package solutions in market. It has been built by a worldwide team of expert developers and includes basic applications such as a web browser, office suite, media application, and instant messaging²³. Skype, the software to allow users to make voice calls through internet, also has Linux based version. Ubuntu regularly releases new versions to support different platforms and include new updates for applications or new driver supports. For secondary PCs, since there are old machines produced years ago, most of drivers for old machines can be supported by Ubuntu latest versions. The development and technology for open OS have been improved greatly and it is becoming more feasible for users to operate in easy and friendly way. The great benefit brought by open OS is that they can also reduce the total cost of infrastructure and improve the situation of dependency in the software developer.

In regard to the license fee of the Microsoft operating system, Microsoft launched three programs for refurbished PCs non-commercial and commercial basis²⁴. Refurbishers can do on-line application and become a member of a Microsoft Refurbisher program. The three programs are:

1. Microsoft Community Authorized Refurbisher: refurbishers who supply refurbished PCs to qualified charities, nonprofits, school and government. Refurbishers pay a unit price of \$6US each for Windows XP or Windows 2000 and Office XP or Office 2000.
2. Microsoft Authorized Refurbisher: for large refurbishers headquartered in Asia, Europe and North America meeting a minimum volume of refurbished PC shipped annually.
3. Microsoft Registered Refurbisher: a new program just launched this spring for small - and medium - sized refurbishers worldwide.

²² See http://www.edu.tw/MOECC/content.aspx?site_content_sn=1571

²³ <http://www.ubuntu.com/products/whatisubuntu/1004features>

²⁴ <http://www.microsoft.com/refurbishedpcs/>

Those programs do provide refurbishers with the opportunities to obtain genuine Microsoft software with low cost and have certain threshold to encourage responsible refurbishment. Similar to an input from one refurbisher about the transaction fee of internet auction, responsible or creditable refurbishers have more willingness to pay the transaction fee and create a market mechanism to encourage good players and discourage informal players in the market.

However, it is still hard to justify the Microsoft license fee for a refurbished PC. If genuine Microsoft software are purchased in a legal way and installed in PCs in the production site, it makes no sense to do double payment to original suppliers for operating system but not other hardware components. On the other hand, Microsoft also launched its UnlimitedPotential program²⁵ to promote secondary PCs in emerging market. It can be a good start to make sure a responsible refurbishing process in place. In the mean time, either for primary user or secondary user, they shall have equal opportunities to get total solution rather than scattered supports. It is important for both software and hardware producers to work together along with the efforts of refurbishers, international organizations and government bodies for establishing a global standard to eliminate critical concerns and deliver a total solution from refurbishment, service to safe disposal to customers in emerging market. Microsoft and Intel can take lead in overcoming those barriers as they have been two boosters for rapid technology changes and replacements.

6.3 Drivers and Barriers Compared to Literature Review

6.3.1 Drivers compared to literature review

There are three additional drivers identified in the stakeholder interviews. Table 6-2 provides the comparison between literature review and stakeholder interviews. The three additional drivers are sustainable consumption perceived by government body, services for commercial customers perceived by producer and opportunities perceived by refurbisher.

Table 6-2 Drivers identified in literature review and stakeholder interviews

| Drivers identified in literature review | Drivers identified in stakeholder interviews |
|---|--|
| 1. Resource Conservation | 1. Resource Conservation |
| 2. Bridge Digital Divide | 2. Bridge Digital Divide |
| 3. Benefits to Low Income Families | 3. Benefits to Low Income Families |
| 4. Profitability | 4. Profitability |
| | 5. Sustainable Consumption |
| | 6. Services for Commercial Customers |
| | 7. Opportunities to New Market |

²⁵ <http://www.microsoft.com/unlimitedpotential/programs/secondarypcs.msp>

6.3.2 Barriers compared to literature review

Comparing to literature review, there are nine additional barriers identified in this research. Table 6-3 provides the comparison between literature review and stakeholder interviews. The nine additional barriers are as follows,

1. Safety, Functionality and Quality Concerns
2. Residual Value Hard to Define
3. Brand Image
4. Higher Toxic Substances of Secondary PCs
5. High Quality Standard and Hard to be Profitable
6. Unreliable Sources
7. Threats to Producers and Recyclers
8. Cost and Availability of Spare Parts
9. Lifetime of Components and Reliability of Used Computer

Table 6-3 Barriers identified in literature review and stakeholder interviews

| Barriers identified in literature review | Barriers identified in stakeholder interviews |
|---|---|
| 1. Small prices differences between New and Used PC | 10. Small prices differences between New and Used PC |
| 2. Lack of Economies of Scale | 11. Lack of Economic Scale |
| 3. Rapid Technological Development | 12. Rapid Technological Development |
| 4. Legislation | 13. Legislation |
| 5. Lack of Available Fleet Machines- High Volumes of Used PCs with Identical Configurations | 14. Low Collection Rate(Lack of Available Fleet Machines- High Volumes of Used PCs with Identical Configurations) |
| 6. High Operational Cost | 15. High Operational Cost |
| 7. Lack of Research and Development, Fragmented Industry and Groupings | 16. Lack of Research and Development, Fragmented Industry and Groupings |
| 8. Software Licensing | 17. Software Licensing |
| | 18. Safety, Functionality and Quality Concerns |
| | 19. Residual Value Hard to Define |

| | |
|--|---|
| | <ol style="list-style-type: none">20. Brand Image21. Higher Toxic Substances of Secondary PCs22. High Quality Standard and Hard to be Profitable23. Unreliable Sources24. Threats to Producers and Recyclers25. Cost and Availability of Spare Parts26. Lifetime of Components and Reliability of Used Computer |
|--|---|

7 Conclusions and Recommendations

In this final chapter, the main findings of the study are summarised, followed by a few concluding remarks. Subsequently, recommendations are made to the three stakeholders – government bodies, producers and refurbishers – that the thesis has focused on. It concludes with a few suggestions on future research.

7.1 Summary of the Main Findings

This first section presents the main findings of this research. It starts from the overview of secondary PC markets, and continues with the key points obtained through the analysis of drivers and barriers perceived by stakeholders and concludes by presenting different scenarios with different level of achievement from environmental, economic and social perspectives.

7.1.1 Overviews of secondary PC market

1. General figures about life cycle of primary PCs and secondary PCs: The global annual PC shipment was over 300 million in 2009, marking ten-time growth in 18 years. By 2014, the estimated shipment will be over 600 million. The number of retired PCs per year has been around 200 million from 2006 through 2010. Worldwide PC penetration rate is 182 PCs per 1,000 persons. US has highest PC penetration rate – 928 PCs per 1000 persons – and its retired PCs accounts for one fifth of global figures. About 22% of the 200 million retired PCs worldwide are in storage, 34% are disposed (recycled, landfilled or incinerated) and 44% are reused through different channels. The worldwide number of PCs being reused has increased from 55 million in 2004 to 86 million in 2007.

2. Supply chain of secondary PCs: PC for reuse is a complex subject. The size of the market, the participants, the points of sources, the activities, the definitions, and the responsibilities are all diverse. Various channels have been used to shift the ownership of the PC from the primary user to the secondary user. These channels include direct sale from the first owner to a buyer, internal reuse within the same household, donation and commercial intermediary transaction. An estimated annual volume of 86 million PCs are reused for commercial (sold through OEM, lesser, reseller or broker) and non-commercial (employee-purchased, end user to end user) resale. If not exported, these PCs are sold mostly to the small businesses or the private home segment. The secondary market is dominated by a handful of large brokers and dealers that buy large volumes of secondary PCs, mainly from large companies, and sell them either to one of the many local resellers specialized in marketing secondary PCs or to exporters. Gartner estimated that in 2008, 37 million secondary PCs were exported for reuse. The number will likely to increase to 69 million by 2012. In general, around 40 to 50% of retired PCs are reused and 40% to 50% of reused PCs are exported.

3. Demand and supply of secondary PCs: Worldwide demand of secondary PCs is still larger than supply. The market for used PCs varies by region, especially as a result of the regulatory environment. Though it is an opportunistic market, it is also highly fragmented with tens of thousands of players involved. Approximately one in three PCs dedicated for reuse is exported from mature to emerging markets. North America, Western Europe, Japan and Australia are the largest exporters of secondary PCs. Most of imported countries are in Latin America, Central and Eastern Europe, Middle East and Asia Pacific regions.

4. Life cycle of primary PCs and secondary PCs in Taiwan: Taiwan enforced its Waste Disposal Act in 1997 that government set up a public foundation –Recycling Management Foundation (RMF) – and producers are financially responsible for end of life disposal of their products. Most of the primary PCs from public and private institutional users are four to six year old and collected for recycling for end of life disposal. Before final treatment in recycling plants, the working components are sorted and reassembled to refurbish PCs for domestic market or export. It represents about 20% to 30% of total collected volumes. Primary PCs retired from large corporation companies in Taiwan are normally two to three years old. Retired PCs are refurbished by the medium-sized refurbisher (also called as broker). The refurbishment rate can be up to 90%. Around 70% of refurbished PCs are exported. Most of the primary PCs especially notebooks from consumers are still stored in the house or closet.

7.1.2 Highlights of drivers and barriers

1. Compared to literatures review: Through semi-constructed interviews with stakeholders, additional drivers and barriers of computer re-use not included in the literatures review of this research are summarised as follows. For policy makers, the objective of sustainable consumption acts as a driver. However, the safety and quality concerns and residual value hard to define perceived as barriers for policy-making. For producers, there is less information about the perspectives of producers on secondary PCs. The services for commercial customers act as a driver. Yet the brand image is one major concern for hardware producers to get involved this highly fragments market. Higher toxic substances of secondary PCs are also issues for producers. Due to rapid technology demand and continuing price decline of new PCs, the profitability mode of IBM addressed in literature review is hard to replicate for other producers. It is also because producers have their quality standards so that the refurbishing business of retired PC is regarded as non-profitable model. In regard to refurbishers, the discussions of unreliable sources, threats to producers and recyclers, the lifetime of components and reliability of used computer and cost and availability of spare parts are not identified in literatures review.

2. Drivers: The Taiwanese government bodies support PC reuse for resource conservation. Secondary PCs can aid to bridge digital divide and benefit low income families or socially disadvantageous groups. It also corresponds to the national consumer policy in Taiwan that incorporates the elements of sustainable consumption. In general, business consumers have more environmental awareness for safe IT disposal. Producer such as Dell with large share of commercial sales provides asset recovery service on used PCs to business customers for selected countries and conserve natural resources meanwhile. Refurbishers try to preserve resources and reuse components or systems when they are still workable. Raw material extraction and manufacturing stage account for large percent of energy use in the lifecycle of a PC. It is irresponsible to recycle still functional components. In general, PC or component reuse and resell give refurbishers higher profits than recycling.

3. Barriers: five factors are commonly perceived by government bodies, producers and refurbishers for secondary PCs. They are small prices differences between new and used PC, rapid technological development, existing regulation, low collection rate (lack of available fleet machines- high volumes of used PCs with identical configurations, and high operational cost. The sixth barrier related to economies of scale is recognized by producers and refurbishers. The seventh barrier about safety, functionality and quality is one of key concerns by government bodies and producers. By looking at legislation side, although the long history and promising achievement of waste recycling schemes and active practices in Taiwan, for PC products, existing governmental interaction – both Waste Disposal Act and national sustainable policy lack central guidelines to promote product reuse. Current Waste Disposal

Act is also associated with high administration cost and low collection rate of mobile PCs from households. Regarding safety, functionality and quality of secondary PCs, international organizations urge for global standardisation of computer reuse requirement. Through the interviews with stakeholders, the safety and functionality of secondary PCs do pose certain risks. A refurbished system without proper ElectroMagnetic Interference (EMI) and Electrostatic Discharge (ESD) solution may have interference on the communication and higher possibility for the systems to freeze up. The impacts of EMI issues on city users will be higher than rural area users. An airport area is a sensitive area as well. As for the issues of mobile PC reuse, the battery is the most critical item for safety. If refurbishers replace used laptop with other non-qualified battery sources, it might have the risk of burning or explosion. The worst case could lead to a house fire.

7.1.3 PC life cycle scenerios with different level of environmental, economic and social ambitions

There are long debates for optimal end of life treatment on hazardous wastes for EE products. According to the learning from stakeholder interviews and literature review in this research, this section provides scenarios with different level of ambitions from environmental, economic and social perspectives.

1. Consideration on environmental aspects only: Primary users use their PCs for a long period of time such as six or seven years and repair as much as possible. In the final disposal stage, discarded PCs are recycled by high standard recycling plant. It assumes there is no dramatic energy efficiency improvement on current and future products.
2. High level of ambition from environmental, social and economic perspectives: Primary users retired their PCs as regular basis. For instance, Global 500 companies renew their IT equipments every three years for company images. It is worthy to note that 140 out of these 500 companies have headquarters in the United States²⁶. The retired PCs from business and home users can be captured and reused through different channels efficiently. If the issues of vested interest groups among policy makers, producers and recyclers can be managed somehow, the priority should be given to domestic market to support local disadvantageous group and prevent future disposal issues such as waste dumping and informal recycling in developing countries. In the end, the end of life PCs can be recycled by high standard recycling facility and raw materials can be utilised for domestic demand. Additional two factors which shall be taken into consideration are the acceptance level of used products by secondary users and high operational costs for PC remanufacturing or refurbishment in mature markets.
3. Medium level of ambition from environmental, social and economic perspectives: The used PCs are retired from primary users, refurbished through standard and qualified process and then exported to the emerging markets nearby. Importers, producers, and local governments work together to establish high standard recycling facilities and provide sufficient incentives to secondary users for final disposal and safe recycling of end of life treatment in emerging markets. For the issue of high operational costs in mature markets, if direct reuse cannot be maxmised, the qualified and standard remanufacturing and refurbishing PC industry can be planned in the nearby emerging market.

²⁶ Fortune 2009 Global 500 <http://money.cnn.com/magazines/fortune/global500/2009/countries/US.html>

4. Low level of ambition from environmental, social and economic perspectives: Some existing problems are really harmful from one or a few of the three perspectives. These problems are, for example, high percentage of retired PCs still stored in closet or wait for repair, used PCs or e-waste shipped to developing countries without proper testing, and informal recycling and recycling facilities operating without proper management standards in developing countries. Under this scenario, at least these problems shall be recognized and resolved.

7.2 Concluding Remarks

The remanufacturing and refurbishing of computers is a complex issue involving various points of sources, activities and participants. Most of the refurbished PCs offered by producers or handled by large refurbishing companies mainly in the United States are relatively new machines generated from commercial returns or other business operations. This research studies the subject of secondary PCs which are used by primary users over three months or longer.

Several significant benefits can be achieved via secondary PCs from social and environmental perspectives – from the social benefits such as provision of access to technology to low income families and bridging digital divides, to environmental benefits related to resource conservation. Moreover, PC refurbishing activities provides new business opportunities for small scale skilful technicians. Producer such as Dell provides asset recovery service for commercial customers and have built the partnership with responsible refurbishers and recyclers in selected countries. Producers can retain customers, achieve higher business margin and reduce environmental impacts by selling services instead of products. However, there are many factors to be considered before establishing a sustainable reverse supply chain, such as reducing the safety risks and functional issues by building up computer re-use standards, seeking opportunities to lower down the cost (user friendly total package of open OS, logistic partnerships, selections of reliable sources and optimal refurbishing locations and procedures), communication, incentives and stable channels for residents to resell or recycle their PCs in a timely manner.

To reflect global e-waste problems from Taiwanese practices, because of low recovery rate of old PC refurbishment (only 20 to 30% for four to six year old PCs obtained from various sources), this research suggests to establish the secondary PC standard as the first priority, request software and hardware producers to take aggressive actions, enlarge domestic market as much as possible and only allow to export the functional secondary PCs meeting standards to certain emerging markets.

7.3 Recommendations

According to different scenarios mentioned above and analyses and discussions of drivers and barriers in Chapter 6, this research summarises recommendations to three stakeholders as follow,

1. Government bodies: to conserve resource and promote sustainable development, government bodies can consider different policy instruments for secondary products/PCs: the regulatory instruments to define national standards to eliminate the safety and functional issues of secondary PCs, encourage the use of open OS and build codes for responsible refurbishing and recycling business, the voluntary/informative instruments to educate consumers and raise consumer awareness to conserve natural resources by repair, reuse or resell their used products in a timely manner and consider to purchase qualified secondary

products. In addition, by encouraging public and private sectors for responsible recycling and reuse, government can work with public institutions and large companies to include certain index in the criteria of national Corporate Social Responsibility (CSR) award to demonstrate best practices for responsible use, reuse, redeployment and recycling. Cloud computing²⁷ can be one of best options to collect old equipments to repair or refurbish and upgrade old computers with new technology. It also can include the programs of employee education about data backup, proper maintenance and upgrade for IT equipments and efficient disposal process to ease refurbishment and recycling process. Moreover, the economic instruments are important to give incentives for consumers to improve the collection rate for ICT products.

For national sustainable policy in general, the concept for material reuse should be integrated. On the other hand, there are more and more product types for consumer electronics. Every brand product or each product model has its own specification for battery, charger and cable. EPA can work with industrial groups for common design of accessories items to improve the overall compatibility. Consumers can reuse the accessory items and producer can reduce their product environmental impacts by less material and packaging use.

For international level, the characteristic of PCs that are different from other electronic products is that they are created based on standard components developed by sub-suppliers, manufactured by ODMs(original design manufacturers) and OEMs(original equipment manufacturers - producers) and sold by retailers. The evolution of processors, software or other key components such as graphic card, hard disk drive and memory chips continue to push industry forward. To find optimal and sustainable scenarios of PC lifecycle, efforts should be made to resolve the environmental and social problems caused by rapid PC development and replacement. Microsoft and Intel are two main boosters for rapid technology changes and replacements. Meanwhile, they have co-branding strategies with PC producers to promote their branding and images for every computer sold. Their gross margins can be up to 80% and 50% respectively²⁸. It is such high figures compared to gross margin of producers ranging from 10% to 30% such as HP, Dell or Acer. Considering the unique characteristic of computer, this research suggests EPR scheme to include processor and software supplier for responsible end of life treatment of PC lifecycle. Policy measures taken by countries with these important actors – most notably the United States – could play an important role.

Furthermore, to discover the optimal approach for PC reuse and recycle, policy works can be separated into commercial and consumer primary users. The priority shall be given to international and national large companies follow Sustainability Reporting Guidelines through Global Reporting Initiative (GRI) for the interests of investors. Large companies are main sources of exported used PC. In addition to two waste criteria (EN 22 and EN 24), GRI index²⁹ can enhance the level to include new index for responsible and qualified resell, refurbishing and recycling practices.

2. Producers: It is important for both software and hardware producers to work together along with the efforts of refurbishers, international organizations and government bodies for

²⁷ Cloud computing is Internet-based computing, sharing resources, software and information provided to computers and other devices on-demand

²⁸ See Microsoft Financial Report 2009 <http://www.microsoft.com/msft/default.msp> See Intel Financial Report 2010 <http://www.intc.com/releaseDetail.cfm?releaseid=377164>

²⁹ <http://www.globalreporting.org/GRIReports/GRIReportsList/>

establishing a global standard to eliminate critical concerns and deliver a total solution from refurbishment, service to safe disposal to customers in emerging market. Producers can also seek for win-win strategies to promote green products with longer warranty period, improve battery lifetime by designing user friendly setting, and consider selling the functions of the PCs instead of the PCs themselves. It is one of HP business strategies for selling services instead of products. Last but not least,, to protect branding image, it is not enough to claim “ban e-waste” export. The reality is that e-waste is not the same as other waste categories with very little residual value. Nor is it the same in terms of toxicity. The toxic trade will continue happening. Under booming social media trend, nothing is more serious than a report or an image which hurts brand image by disclosing used PCs with brand companies’ logo dumped or improper recycled by women or children under terrible conditions in developing countries. Software and hardware PC producers shall look for optimal solutions at international level to solve the toxic trade problems. E-waste problem will not be solved today or tomorrow. It will require lots of studies, discussions, planning and implementations. Producers, especially fast growing companies such as Acer, need to take aggressive actions to prevent any damage of brand image in the near future.

3. Refurbishers: governments have some resources for technical support to improve the remanufacturing and refurbishing operations. Refurbishers can apply for government projects and work together to establish national standards. While the national standard is established, the qualified refurbishers can build the network to improve the transactions of used components and PCs and share their experiences related to the upgrade of hardware and software. The recovery rate can be up to 65 to 90% for refurbishments of two to three year old PCs retired from commercial users. However, only around 20 to 40% yield rate have been achieved for refurbishments of PCs which are older and obtained from various sources. The quality, timing and quantity of returned PC are important issues for reverse logistics. Refurbishers can consider building strategic business models and enlarging business scales. Similarly to a second-hand market approach of Bestbuy³⁰, a specialty retailer of consumer electronics in the United States and Canada, refurbishers can consider building a partnership with some retail chain stores to sell and collect used computers from consumers and have proper communications or sales package to private consumers in advance for efficient collection and refurbishment. For efficient collection, in Taiwan, there is a successful model for dry cell battery recycling. The second biggest convenience store, FamilyMart, runs the program to encourage private consumers to properly recycle and exchange used batteries, mobile phones and computers for boiled eggs, hotdogs and cold drinks³¹. In total 2350 stores run this program and have collected 100 tones of battery in five months. The first biggest convenient store, 7-Eleven, proposed a similar program recently to the medium-sized refurbisher. However, due to the differences of internal business groups in 7-Eleven of Taiwan, there is no agreement so far in terms of logistic issues.

7.4 Future research

This research tries to illustrate the framework of PC re-use activities and provides a background study for secondary PCs to respond to growing e-waste problems. It is a little step and requires continuous works to improve overall lifecycle performance of PCs toward sustainable development through international collaboration and cooperation.

³⁰ http://barryjudge.com/secondary-markets-a-new-growth-opportunity-for-best-buy?sms_ss=facebook

³¹ http://www.family.com.tw/enterprise/news_in.aspx?ID=140

This section summarises the directions not covered by this research and makes following suggestions for future research.

1. Categories and activities: Some demand and supply site studies such as the surveys of primary users, brokers and secondary users, the internet auction, exports of non-working PC, leasing programs and commercial returns.
2. Geographies: the fastest-growing regions in terms of demand are the Middle East and Africa (MEA) and in Asia/Pacific. The countries from supply sites are the United States and Western Europe countries.
3. Focused countries: by taking some figures into account, United States shall be one of focused countries to study. The reasons are many: highest PC penetration rate per 1000 persons, accounted for one fifth of total retired PCs per year, 140 out of global 500 biggest companies have their headquarters in the United States, main hardware and software producers from the United States – Intel, Microsoft, HP and Dell. According to Microsoft Authorised Refurbished Program, there are total 19 large refurbishers located in North America³². In the mean time, United Parcel Service in the United States established a green disposal network since 2000 to ensure proper recycling by continuing auditing, surprising visiting and tracks every piece of equipment throughout its recycling trail (UPS, 2009). Germany, also a quick adopter of the latest IT trend, can serve as comparative case regarding the exportation of used electronics.
4. Full Life Cycle Assessment of Mobile PC including netbook and tablet PC: Without full life cycle assessment for computer to include recent figures for raw material extraction, manufacturing, usage and final disposal (dumping and landfills, recycling-low and high standard, and open burning), it is still hard to determine if it is better to recycle or reuse a used PC. To have a clear understanding on environmental impacts of mobile PC or netbook, it is crucial to re-evaluate the environmental impacts on the stages of raw material extractions and productions. According to the inputs from HP environmental managers, to extract the metal out of the rocks, it requires the excurvation of rocks 20 to 30 times more than earlier years. In the mean time, to manufacture a chip, Taiwan Semiconductor Manufacturing Company, the world's largest dedicated independent semiconductor foundry based in Taiwan, makes annual improvements on its energy use, water use and chemical use. Taiwanese industries in notebook computers, foundry, and motherboard manufacturing sectors account for 84%, 68% and 99% worldwide market respectively (MOEA 2009). The production sites are mainly located in China and Taiwan. To collect more raw material data for life cycle analysis of electronic products, more resources and focuses are essential in the international cooperation with China and Taiwan.

³² Find details about refurbishers in North America <http://www.microsoft.com/refurbishedpcs/Programs/MAR.htm>

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Appendix

Table A-1 Refurbisher Group Survey of Driver and Barrier

| | | |
|--|-------------|---------------|
| Company Profile | | |
| Company Name | | |
| Company Headquarter | | |
| Employee Number | | |
| Name of Director | | |
| Business | | |
| Founded in | | |
| | | |
| General Questions | | |
| Refurbishment Process | | |
| Sources of used PC | | |
| Average Recovery Rate | | |
| Average Operation Hour | | |
| Average Sales Qty.per month | | |
| Cost and Profit | | |
| Warranty and Operating System | | |
| | | |
| | Weak | Strong |
| Drivers | | |
| Resource Conservation | | |
| Bridge Digital Divide | | |
| Benefits to Low Income Families | | |
| Profitability | | |
| | | |
| Barriers | | |
| Small prices differences between New and Used PC | | |
| Lack of Economies of Scale | | |
| Rapid Technological Development | | |
| Legislation | | |
| Lack of Available Fleet Machines- High Volumes of Used PCs With Identical Configurations | | |
| High Operational Cost | | |
| Cost and Availability of Spare Parts | | |
| Unreliable Sources | | |
| Lifetime of Components and Reliability of Used Computer | | |
| Threats to Producers and Recyclers | | |
| Software Licensing | | |

Table A-2 Personal Communication

| Interviewees | Affiliations | Timing |
|---------------------|--|---|
| Lill Lindbäck | Nordic Take back Manager Dell Sweden | 2010/Apr/21 phone interview,2010/May/05 email communication |
| Richard Lai | Executive Director, Corporate Sustainability Office,Acer Inc.(Taiwan) | 2010/Apr/25 phone interview |
| Jean Coxkearns | Snr. Take Back and Recycling Manager, Dell EMEA | 2010/May/18 email communication |
| Klaus Hieronymi | Chairman of the Environmental Board, Europe, the Middle East and Africa, Hewlett-Packard | 2010/May/10 phone interview |
| Christine Chiang | Environmental Manager, HP-Asia Pacific(Taiwan) | 2010/Mar/24 semi-constructed interview |
| Yuan-Jang Huang | Tripe-E Institute,Program Manager | 2010/Mar/28 in-depth interview |
| Jiun-Hau Kang | ASUSTek,Program Engineer | 2010/Mar/12 in-depth interview |
| Yuan-Jang Huang | Tripe-E Institute,Program Manager | 2010/Mar/28 semi-constructed interview |
| wenlingchi | IER,Senior Researcher | 2010/Feb/24 semi-constructed interview |
| Shih-Chi Liao | CPC,Policy team leader | 2010/Apr/26 phone interview |
| Jen-Hsiung Cheng | EPA,EE RFM team leader | 2010/May/10 phone interview |

Table A-3 Per-PC Various Disposal Options: activities and cost associated

Cost associated: X marked

| Per PC | Labor Rate | Time | Employee Sale | Charitable Donation | Brokered Sale or Auction | Total Destruction | Trade-In | Outsource |
|---|------------|------|---------------|---------------------|--------------------------|-------------------|----------|-----------|
| Admin. Tasks | X | X | X | X | X | X | X | X |
| Staging Equipment | X | X | X | X | X | X | X | X |
| Backing Up Hard Drive | X | X | X | X | X | X | X | X |
| Sanitizing Hard Drive | X | X | X | X | X | | X | |
| Reloading Operating System | X | X | X | X | X | | X | |
| Testing PC | X | X | X | X | X | | X | |
| Follow-On Technical Support | X | X | X | | | | | |
| Processing Payments | X | X | X | | X | | | |
| Preparing Transfer Documents | X | X | X | X | X | X | X | X |
| Disposal Fee | | | | | | X | | |
| Packing | X | X | X | X | X | X | X | |
| Shipping | | | X | X | X | | X | X |
| Outsourcing Fee | | | | | | | | X |
| Total | | | X | X | X | X | X | X |
| <i>Less Sale Proceeds</i> | | | X | | X | | X | X |
| Per-PC Costs (1-highest; 6-lowest) | | | 1 | 2 | 6 | 3 | 4 | 5 |