The Household E-Waste Management in Thailand: Challenges and Opportunities towards Circular Economy

Aweewan Panyagometh*

Received: August 30, 2023 *Revised: April 11, 2024* *Accepted: June 04, 2024*

Abstract

Thailand has been facing challenges in handling e-waste as the country does not have regulations on e-waste management. Most of the practices are being performed by informal sectors that lack technology, infrastructure, and knowledge. This research aims to understand the e-waste management and challenges and opportunities towards circular economy. The results show that the transportation distances from households to recycling facilities passes through many middlemen before arriving at a recycling company's gate. If this e-waste had been collected and recycled, it can create value added and reduce CO_2 emissions at the same time. To achieve the circular economy, the logistic should be improved. For certain type of e-waste, the fee might be charged form consumers. Full recycling facilities (e.g. circuit board, battery) is needed. Appropriate legislation dealing specifically with e-waste, control of its dumping, implementation of extended producer responsibilities are the key issues to promote circular economy of e-waste.

Keywords: E-waste Management, Circular Economy, E-waste Recycling, E-waste Management flow

* International College, National Institute of Development Administration
148 Seri thai Road, Khlong-Chan, Bangkapi, Bangkok 10240, THAILAND.
E-mail: aweewan.m@nida.ac.th

การจัดการขยะอิเล็กทรอนิกส์ในครัวเรือนในประเทศไทย: ความท้าทายและโอกาสสู่เศรษฐกิจหมุนเวียน

อาวีวรรณ ปัญญาโกเมศ*

รับวันที่ 30 สิงหาคม 2566 *ส่งแก้ไขวันที่ 11 เมษายน 2567* *ตอบรับตีพิมพ์วันที่ 04 มิถุนายน 2567*

บทคัดย่อ

ประเทศไทยพบว่ามีความท้าทายในการจัดการขยะอิเล็กทรอนิกส์เนื่องจากขาดการกำหนดข้อบังคับในการจัดการของขยะอิเล็กทรอนิกส์ การดำเนินการส่วนใหญ่นี้มักถูกดำเนินโดยส่วนผู้ประกอบกิจการรายย่อย เกษตรกร ซึ่งขาดความรู้ทางเทคโนโลยี โครงสร้างพื้นฐาน และความเข้าใจ งานวิจัยนี้มีวัตถุประสงค์เพื่อเข้าใจการจัดการของขยะอิเล็กทรอนิกส์และความท้าทายและโอกาสที่เกี่ยวข้องกับหลักเศรษฐกิจหมุนเวียน ผลการวิจัยแสดงให้เห็นว่าระยะทางการขนส่งจากครัวเรือนไปยังสถานที่รีไซเคิลผ่านผู้กลางหลายคนก่อนมาถึงประตูของบริษัทรีไซเคิล ถ้าหากขยะอิเล็กทรอนิกส์นี้ถูกเก็บรวบรวมและรีไซเคิลได้ มันสามารถสร้างมูลค่าเพิ่มและลดการปล่อยก๊าซคาร์บอนไดออกไซด์พร้อมกัน เพื่อทำให้เกิดเศรษฐกิจหมุนเวียน การจัดการโลจิสติกส์ควรปรับปรุง เพื่อประสบความสำเร็จ สำหรับประเภทขยะอิเล็กทรอนิกส์บางประเภทอาจมีค่าธรรมเนียมจากผู้บริโภค การมีสิ่งอำนวยความสะดวกที่เกี่ยวข้องอย่างเต็มรูปแบบ (เช่น แผงวงจร แบตเตอรี่) เป็นเรื่องสำคัญ การบังคับกฎหมายที่เกี่ยวข้องโดยเฉพาะกับขยะอิเล็กทรอนิกส์ การควบคุมการจำหน่าย การปฏิบัติหน้าที่ของผู้ผลิตที่ถูกขยายออกไป เป็นปัจจัยสำคัญในการส่งเสริมเศรษฐกิจวงจรของขยะอิเล็กทรอนิกส์

คำสำคัญ: การจัดการขยะอิเล็กทรอนิกส์ เศรษฐกิจหมุนเวียน การรีไซเคิลขยะอิเล็กทรอนิกส์ การจัดการขยะอิเล็กทรอนิกส์

* วิทยาลัยนานาชาติ สถาบันบัณฑิตพัฒนบริหารศาสตร์
เลขที่ 148 ถนนเสรีไทย แขวงคลองจั่น เขตบางกะปิ กรุงเทพฯ 10240
อีเมล: aweewan.m@nida.ac.th

Introduction

The production and use of electrical and electronic devices have rapidly increased and, as technology changes fast, the prices of these products have decreased, causing the rapid changes to new models. This shortens the life expectancy of electrical and electronic equipment. Therefore, the country should be concerned about the issue of electrical and electronic waste management in all sectors.

E-waste includes discarded electrical and electronic devices that enter the waste stream from various sources— out- dated air conditioners, telephones and cell phones, personal computers, electronic toys, televisions, and others (Mundada et al., 2004). E-waste is classified as a hazardous substance because the parts contain heavy metals and hazardous chemicals. Improper disposal by burning or landfilling will directly harm people's short- and long-term health and the environment, such as the underground sources of surface water (Buranasingha, 2016). For example, cathode-ray tubes (CRTs) used in television and computer monitors contain significant amounts of lead. In addition, printed circuit boards contain plastic, copper, chromium, lead solder, nickel, and zinc. Many other electronic products have batteries that contain nickel, cadmium, and other heavy metals (Mundada et al., 2004).

The quantity of e-waste all types discarded in Thailand in 2012 was 357,000 tons and increased to 384,233 tons and 421,335 tons in 2015 and 2019, respectively, and this tonnage is likely to increase by more than 40% in the next 10 years (Manomaiwiboon, 2018, Pollution Control Department, 2019).

Over 35 countries, notably western European countries, have adopted legislation for the management of electrical and electronic product waste. In Asia, Japan, Taiwan, China, and India have been implementing their respective e-waste regulations. Other countries are in the process of enacting legislation, such as Vietnam, Indonesia, and Laos (Klangphol et al., 2019). Many developed countries have applied extended producer responsibility (EPR) and developed very clear regulations for e-waste management; for example, Japan enforced the Container and Packaging Recycling Law in 1997 and the Law for the Recycling of Specified Kinds of Home Appliances in 2001. The latter law covers four home appliances: TV sets, air conditioners, refrigerators, and washing machines. Freezers were added to the list in April 2004 (Kojima et al., 2009). Consumers pay disposal fees at the time of purchase.

On the contrary, many developing countries either have not imposed any regulations or failed to implement such a policy. For example, Thailand does not have regulations on e-waste management. In additions, the country still lacks necessary data/inconsistent information about the amount of e-waste as well as a facility for collecting, dismantling, and recycling.

The unorganized or informal sectors have long been actively involved in e-waste collection, handling, dismantling, and recycling. However, their activities are mainly being performed without technology, infrastructure, and knowledge.

Meanwhile, the activities of these informal sectors can have serious impacts on the environment and human health. The informal dismantling and recycling workers are scattered nationwide and are divided into sorting and dismantling communities. Although some communities are aware of the hazardous substances in e-waste, most communities are more concerned with their current livelihood than their health and environmental issues. In communities where all households operate according to the same practices for sorting and dismantling, there is competition for the acquisition of the wastes. As a result, workers search for e-waste outside their designated areas and go longer distances and take a longer time to get their desired amount of waste.

The circular economy is an economic system aimed at minimizing waste and making the most of resources. Unlike the traditional linear economy, which follows a “take, make, dispose” model, the circular economy seeks to keep products, components, and materials at their highest utility and value at all times. In essence, it's about creating a closed-loop system where resources are continuously reused, recycled, or repurposed (The Ellen MacArthur Foundation, 2023).

The four key successes of e-waste management involves these following aspects: economic, environmental, social, and technology (Fetanat et al., 2021). Importantly, it is impossible to design effective e-waste policies toward circular economy if the government does not know the amounts of e-waste and their distribution flow, second-hand markets, the informal sorting and recycling sectors, and export quantities and destinations. Based on all of this background, the objectives of this study are:

1. Collect statistical data on the amount of e-waste and distribution per province (focusing on four types of e-waste: TVs, desktop computers, air conditioners, and cell phones)
2. Study the current quantity of e-waste distribution and create a geographic information system (GIS) showing the quantity of distributions and the sorting, dismantling, and recycling of e-waste.
3. Provide recommendations for e-waste management.

The contribution of this study is to understand the situation of e-waste management in Thailand and to provide better disposal practices towards circular economy. In addition, this study are to help government, recycling sectors, and society understand e-waste generation, disposal behaviors, and e-waste management in Thailand to design effective e-waste policies towards circular economy. This study can be the case that represents the country that lack of the e-waste management regulations. Challenges and opportunities are discussed.

Methodology

Estimated amount of e-waste generated per year and understanding the flow of e-waste in Thailand

Estimated amount of e-waste generated per year based on government data

Some government agencies reported estimated e-waste, however, their data are inconsistent. Thus, to understand the e-waste generated, secondary data were compiled from the Pollution Control Department (Pollution Control Department, 2012b, Pollution Control Department, 2012a, Pollution Control Department, 2012c, Pollution Control Department, 2019) and the Department of Industrial Works (Department of Industrial Works, 2018). See Table 1 for the summary of methods for estimating four types of e-waste and distribution by province and Tables A1-A2 for estimated e-waste detail.

Table 1: Summary of Methods for Estimating Four Types of E-waste and Distribution by province

Product	Estimation Amount of E-Waste		E-Waste Distribution by Province	
	Methods	Sources	Methods	Sources
Cell phone	1) Estimate quantity of e-waste by each category 2010-2050 2) Forecast of domestic electronic and electric devices sales 2012-2025 3) Forecast of e-waste 2012-2026 4) Cell phone sales in Thailand 2016-2019	Department of Industrial Works (2018) Pollution Control Department (2012b) Pollution Control Department (2012b) (Online manager, 2019; IT DAY, 2020)	Use data on the number of mobile phone usage by province of the population aged 6 years and over. Use this data to distribute discard mobile phone in 2019. See section 3.1.1.	tional Statistical Office (2018)
Desktop computer	1) Estimate the quantity of e-waste by each category 2010-2050 2) Amount of e-waste 2012-2019 3) Forecast of domestic electronic and electric devices sales 2012-2025 4) Forecast of e-waste 2012-2026 5) Number of desktop computers used in a household 2014–2018	Department of Industrial Works (2018) Pollution Control Department (2019) Pollution Control Department (2012b) Pollution Control Department (2012b) National Statistical Office (2018)	Used data on the number of desktop computers used in households by province to distribute discarded desktop computer in 2019. See section 3.1.1.	National Statistical Office (2018)
Air conditioner	1) Estimate the quantity of e-waste by each category 2010-2050 2) The amount of e-waste 2012-2019 3) Forecast of domestic electronic and electric devices sales 2012–2025 4) Forecast of e-waste 2012–2026 5) Number of domestic air conditioners sale 2010-2019	Department of Industrial Works (2018) Pollution Control Department (2019) Pollution Control Department (2012b) Pollution Control Department (2012b) Office of Industrial Economics (2015)	Used data on the number of households that have air condition by province multiply with total number of households in each province. Then distribution of discarded air condition in 2019 can be calculated. See section 3.1.1.	National Statistical Office (2015) Office of Industrial Economics (2019)
Television	1) Estimate the quantity of e-waste by each category 2010–2050 2) Amount of e-waste 2012–2019 3) Forecast of domestic electronic and electric devices sales 2012–2025 4) Forecast of e-waste 2012–2026	Department of Industrial Works (2018) Pollution Control Department (2019) Pollution Control Department (2012b) Pollution Control Department (2012b)	Use data on the number of households that have TV then multiply with the number of households by province. Then the distribution of discarded TV by province can be calculated. See section 3.1.1.	National Statistical Office (2017) National Statistical Office (2019)

The National Statistical Office, Office of Industrial Economics, and newspaper also reported data on air conditioners, mobile phones, and desktop computers used in households (National Statistical Office, 2015, National Statistical Office, 2017, National Statistical Office, 2018, National Statistical Office, 2019, Office of Industrial Economics, 2015, Office of Industrial Economics, 2019, Online manager, 2019). For the sale data or the number of devices used in households were obtained from secondary data. The average lifetime usage data was from questionnaires (detail is discussed in section 2.1.3) and secondary data. Then, the amount of e-waste generated was estimated. To find the distribution of e-waste distribution by each province, the equations below were applied.

For cell phones and desktop computers:

$$\frac{\text{(Number of discarded celll phones in 2019 x Number of users by each province age above 6 years old)}}{\text{Number of users age above 6 years old nationwide}} \quad (1)$$

For TVs and air conditioners:

Due to data limitations, there are two steps to calculate the distribution of discarded e-waste by province.

1) Use the data on the number of households with air conditioning in 2015 in each region. In 2015, there were 5.1 million households nationwide with air conditioning. It is distributed in different regions as follows: Bangkok, 1.4 million households; Central region, 1.9 million households; Northern region, 0.7 million households; Northeastern region, 0.6 million households; and Southern region, 0.5 million households. The equation below was used to calculate the number of households by province that have an air conditioner.

$$\frac{\text{(Number of households by province in 2019 x Number of households that have air conditioners)}}{\text{Number of households by region}} \quad (2)$$

2) Take the number of households that have air conditioners by province (from step 1) and multiply it by the number of discarded air conditioner in 2019, resulting in the total distribution of discarded air conditioners in 2019 by province.

$$\frac{\text{(Number of households that have an air conditioner by province x Total discard air conditioner in 2019)}}{\text{Total number of households that have an air conditioner nationwide}} \quad (3)$$

E-waste component

The components of e-waste that can be reused, recycled, or wasted were also estimated. This study reported both primary and secondary data. The researcher dismantled e-waste and weighted each part following the guideline from workers in the e-waste sorting and dismantling communities.

Understand consumer behaviors by questionnaires

The questionnaires were developed to understand consumers' behaviors when their electric and electronic devices reach their end-of-life. The target groups are general people who own electric and electronic devices. Questionnaires were distributed around 400 through an online platform. The snowball sampling method was employed in this study. The questionnaire consisted of three parts: general information, consumer behavior, handling behavior after use (see supplement data).

Understand e-waste flow by site visit and interviews with related stakeholders

To understand the e-waste flow and end-of-life management throughout the supply chain, a field survey and interviews of stakeholders related to e-waste management were conducted. The stakeholders were (1) e-waste collection and transportation, (2) recycling industries (industrial code 106), (3) sorting and dismantling community and industries (Industrial code 105), and (4) waste management (industrial code 101). In addition, government agencies involved in e-waste management were selected for interviews; for example, the Department of Primary Industries and Mines, Pollution Control Department, the Department of Industrial Works, and local governments (Table 2).

Table 2: Summary of Stakeholders (e.g., business groups and government agencies) Related to Waste Management.

Stakeholders	Sample Size	Methods
1) Businesses where products or parts are repaired and reused or sold (refurbishing)	4 shops	Search for data from the Internet and contact for interview
2) Dismantling and recycling industries (industrial codes 105 and 106) - Dismantling community - Re-call discard cell phone project - Second hand shop - Private companies	- 3 locations (10 shops) - 3 projects - 3 shops - 4 shops	- Site visit and interview 3 locations in Buriram, Kalasin, Bangkok - Secondary data - Randomly selected stores for interview - Randomly selected stores for interview and secondary data
3) Business related to both reuse and recycling (refurbishing and re-cycle) - Non-profits organization and associations (donations)	- 3 organizations - 1 shop	- Site visit and interview - Site visit and interview - Contact local government for data
- Private companies - Dismantling community (cell phones)	- 1 location (Mahasarakarm Province)	
4) Business related to disposal (disposal) from e-waste (industrial code 101) - Hazardous waste collection by government agencies - Waste disposal companies (101)	- 3 companies - 2 companies	- Site visit and interview - Site visit and interview/ secondary data
5) Government agencies - Department of Primary Industries and Mines - Pollution Control Department - The Department of Industrial Works - Local governments (Bangkok, Kalasin, Burirum provinces)		- Site visit and interview/ secondary data

Developing GIS database for the collection, dismantling, and recycling of e-waste

The researcher collected the location data of secondhand shops, repair shops, dismantling facilities, and recycling industries nationwide and displayed them on a map. The location data of donation organization, secondhand shops and repair shops were obtained by contacting local governments for the shops listed and compiling data from Internet (Tables A3-A4). The data of dismantling facilities (industrial code 105), recycling industries (industrial code 106), and waste disposal (industrial code 101) were collected from Department of Industrial Works (see Tables A5-A7). The locations were then displayed using GIS. The transportation distance between shops/ facilities/industries can be calculated.

Results

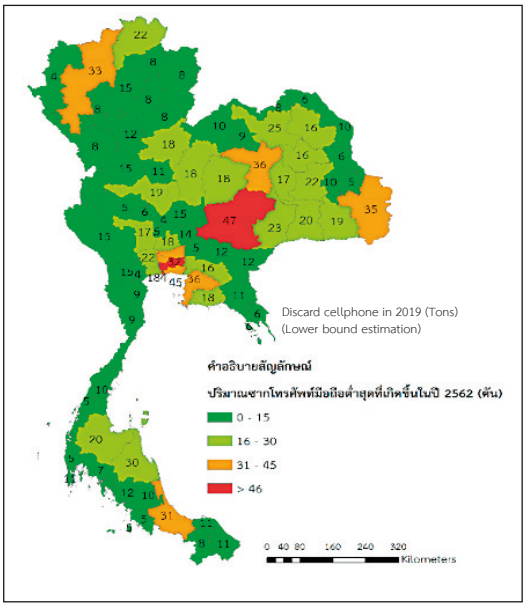
Estimated household e-waste generated in 2019 and distribution in each province

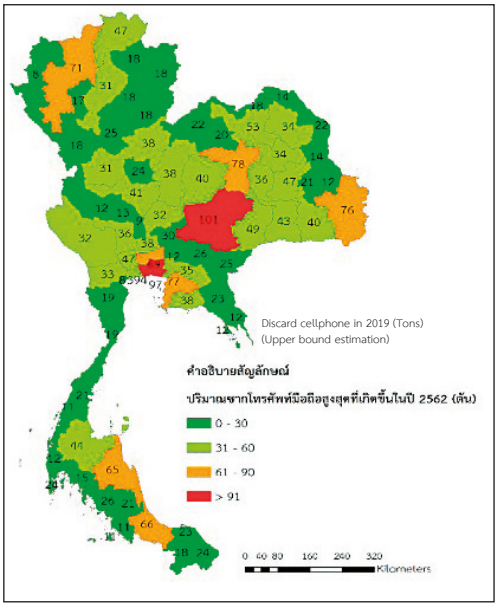
This section shows the e-waste estimates of the quantities of the four types of products (TVs, air conditioners, desktop computers, and cell phones) in 2019. There were approximately 89,499-257,567 total tons, with the highest distribution of all products being in Bangkok, followed by Samut Prakan, Nakhon Ratchasima, and Chonburi. This e-waste can be divided into 1) cell phones, 1,343–2,875 tons, or 10.74–23.00 million units, distributed in three provinces with more than 90 tons per province: Bangkok, Nakhon Ratchasima, and Samut Prakan; 2) desktop computers, 16,250–58,178 tons, or 1.25–4.47 million units distributed in seven provinces with a volume of more than 1,500 tons per province: Bangkok, Samut Prakan, Nonthaburi, Pathum Thani, Chonburi, Chiang Mai, and Nakhon Ratchasima; 3) air conditioners, 34,884-97,066 tons, or 0.91–2.54 million units distributed in three provinces with a volume of more than 3,000 tons per province: Bangkok, Samut Prakan, and Chonburi; and 4) televisions, 37,022-99,448 tons, or 2.46–6.80 million units distributed in three provinces with more than 3,000 tons per province: Bangkok, Nakhon Ratchasima, and Samut Prakan (Table 3). As shown in Figure 1, the e-wastes were clustered in the central part of the country.

Table 3: Summary of the Quantity of E-waste in 2019

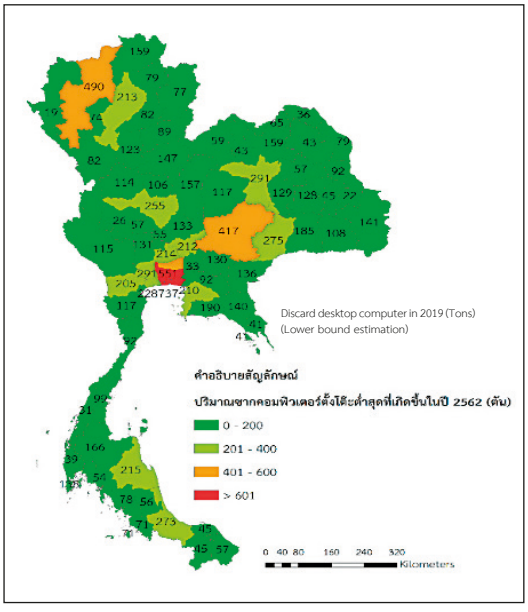
Method	Data Source	Quantity of E-waste in 2019 (tons)				Total (tons)
		Cell phones	Desktop Computers	Air Conditioners	Televisions	
1	Forecast of e-waste: the Ministry of Industrial Works (2018)	1,343	21,353	60,971	37,022	120,689
2	Forecasted e-waste: Pollution Control Department (2019)	-	23,168	77,653	99,448	200,269
3	Forecast of product sales: Pollution Control Department (2012)	1,647–1,710	16,413–17,523	36,066	50,598	104,724–105,897
4	Forecasted e-waste: Pollution Control Department (2012)	1,561	16,250	34,884	46,50 6	99,201
	Smartphone sales: Consultant and Marketing Information Research Co., Ltd.	2,875	-	-	-	2,875
	Number of desktop computers used in household: National Statistical Office	-	58,178	-	-	58,178
	Air conditioner sales: Office of Industrial Economy	-	-	97,066	-	97,066
Summary of carcass quantity (Minimum-Maximum)		1,343–2,875	16,250–58,178	34,884–97,066.	37,022–99,448	89,499–257,567

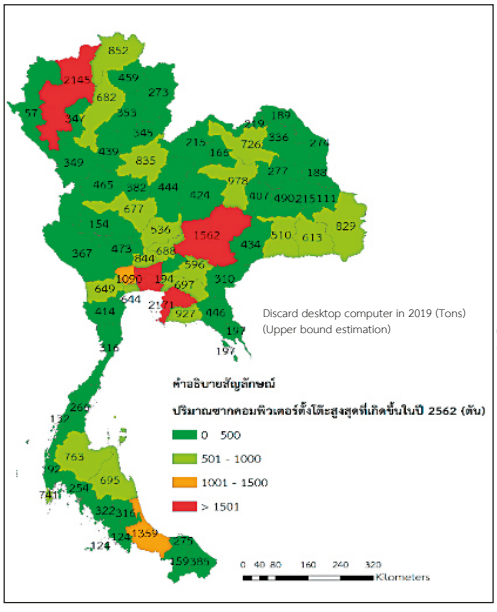
Note: Dash (—) means no data were collected





(a) Cell phones





(b) Desktop computers

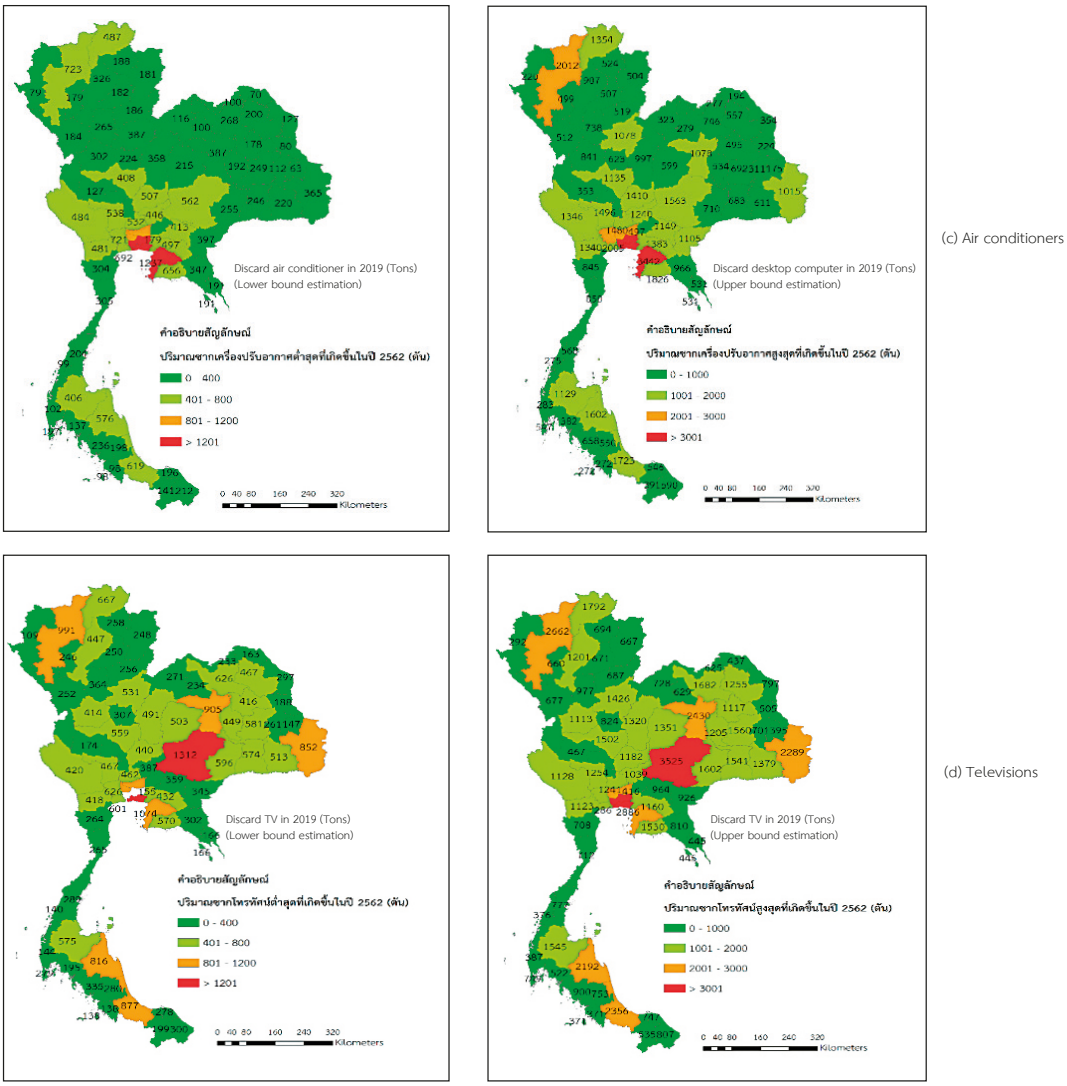


Figure 1: Distribution of Discarded E-waste: (a) Cell Phones; (b) Desktop Computers; (c) Air Conditioners; (d) Televisions

E-waste components

If these wastes were sorted and dismantled, the scrap can be divided into three categories: which are 1) waste (non-recyclable parts e.g. glass, plastic and back light), accounted for 24 percent or 24,770-80,062 tons 2) recyclable parts that are recycled domestically (e.g. plastic, iron, copper and aluminium), accounted for 70 percent or 68,859-231,032 tons and 3) recyclable parts that are exports (e.g. boards and phone batteries), accounted for 6 percent or 5,998-19,965 tons (Table 4).

Table 4: Types and Amounts of Waste from Dismantling Facilities in 2019

Carcass	Garbage Type	Volume (tons/2019)
Cell phones	Front cover/back cover (plastic) Screen (glass) Other	215-460 430-920 67-144
Total		712-1,524
Desktop computers (CRT monitors and CPUs)	Computer screen glass fragments Plastic Others (carbon plate and power cord)	3,963-26,762 142-172 4,887-5,992
Total		8,992-32,926
Air conditioners	Others (power cable and cable)	348-1,358
CRT screen televisions	Broken glass tv screen Plastic Back light Others (carbon plate power cord)	12,095-37,322 24-76 2,162-5,652 437-1,204
Total		14,718-44,254
Include all the waste generated		24,770-80,062

E-waste management flow and consumer behaviour

Electronic waste in Thailand found that although the origin of electronic waste in the country is different (industrial and community sources), but the destination of those electronic waste components is the same depending on the type and value of a piece. The parts that have high value (electronic circuit boards and batteries) are exported for recycling abroad in Singapore and South Korea, while low-value parts (plastic, copper, steel and aluminium) are recycled by domestic recyclers. Moreover, all the waste generated from the sorting process remains in the country which has both properly eliminated and illegal dumping.

According to survey, consumers reported 4 main choices of discarding e-waste such as 1) selling e-wastes to collectors or peddlers 2) donating to non-profit organizations for repairing and reselling e.g. temples, handicap association, orphanage center 3) donate to e-waste collection projects conducted by various organization, e.g., Electricity Generating Authority of Thailand, universities, a mobile signal provider, department stores etc. Usually, these projects prepare collecting points in designated locations and they are just temporary 4) discard e-waste along with household solid waste.

As for the general information, the response rate was 80 percent, and the respondents were from 26 provinces across the country. The average use age of devices was reported as summarized in Table 5. The results of this study fall in the same range of estimated with the previous studies. The average usage of cell phones was 3.09-4.51 years, desktop computers 3.65-7.54 years air conditioners 5.20-10.00 years, televisions 5.35-9.76 years.

Table 5: The Average Use Age (years)

E-waste	Average use age (years)		
	This study	Pollution Control Department (Pollution Control Department, 2012a)	Industrial works (Department of Industrial Works, 2018)
Cell phone	3.86	3.09	4.51
Desktop computer	5.54	3.65	7.54
TV	9.76	5.35	8.34
Air conditioner	9.10	5.20	10.00

According to the survey, Figure 2 showed various channels of each type of e-waste are discarded differently. For cell phone, approximately 79 percent of respondents chose to keep at home because mostly they are afraid of data leaking, do not know collecting point, or etc.; 8 percent sell to informal collectors; since the cell phone is small device, 2 percent discarded with household waste. For desktop computer, keeping at home and sell to informal collector are approximately 29 and 30 percent, respectively; 28 percent is donated to non-profit organizations. For air conditioner, 63 percent is sold to air repair shops. For TV, consumers chose to sell to informal collectors as the largest percentage, 57 percent. When compare with previous studies, this study falls in the same range with the previous studies (Table 6).

Table 6: Percentage of E-waste Management from Various Channels

Channels of discard e-waste	This study*	Department of Industrial Works*(Department of Industrial Works, 2018)	Pollution Control Department** (Pollution Control Department, 2012a)
Keep at home	32	-	52
Sell to informal collectors	44	43	8
Sell to repair shop		19	-
Donate	14	33	23
Exchange for new	-	-	5
Discard with household waste	2	6	11
Other	8	-	-

Note:
* This is the average percentage of 4 products (mobile phones, computers, air conditioners and televisions).
** This is the average percentage of all products studied (10 products) surveyed from the group.
- no survey/no data

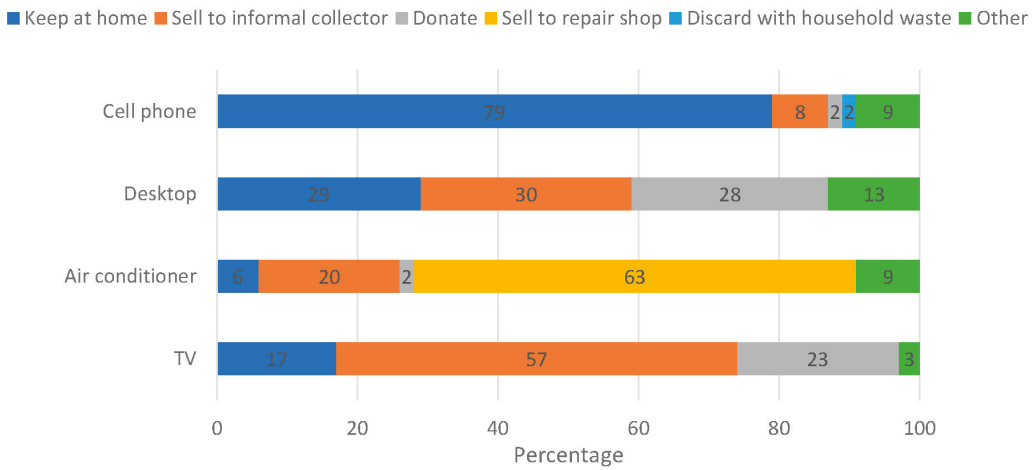
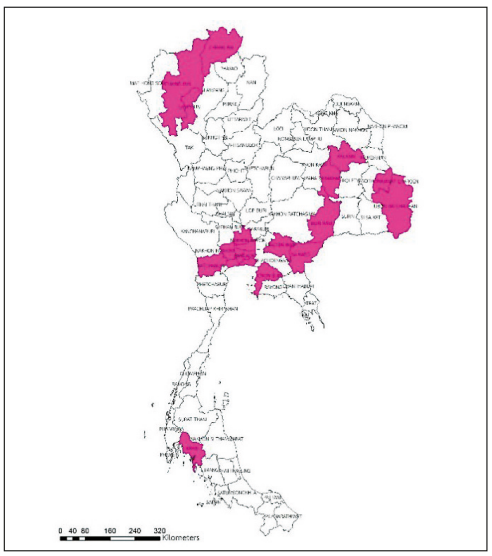


Figure 2: Consumers' Behavior of Handling Household E-waste

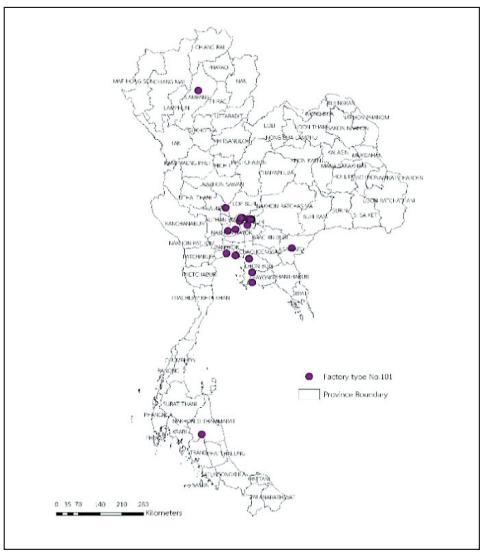
The consumer behaviour is quite similar to Indian. Borthakur and Govind (2019) reported that 59.3% of computer and cell phone waste in urban Indian are retained their obsolete electronics due to lack of knowledge about proper e-waste management (Borthakur and Govind, 2019).

GIS database on the locations of communities sorting and dismantling and recycling facilities

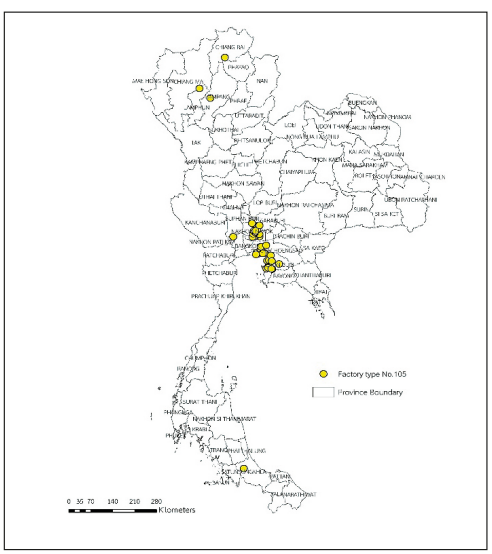
According to the Thailand Development Research Institute (TDRI; 2016), there were e-waste sorting communities nationwide in 17 provinces as shown in Figure 3a)



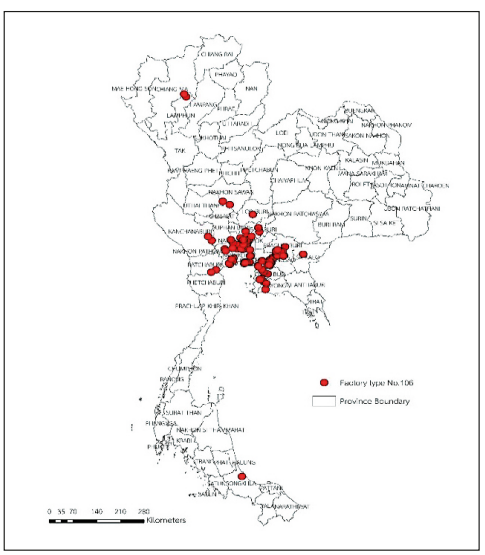
(a) Sorting/Dismantling Communites



(b) Industry Code 101 Waste Treatment



(c) Industry Code 105



(d) Industry Code 106

Figure 3: The Locations of Industries 101, 105, and 106 and Sorting/Dismantling Communities: (a) Sorting/ Dismantling Communites; (b) Industry Code 101 Waste Treatment; (c) Industry Code 105; (d) Industry Code 106

(Thailand Development Research Institute (TDRI), 2016, Wasanadamrongdee, 2015). The main locations of sorting communities which have been active for more than 10 years are Kalasin and Buriram provinces (the region that has the lowest GDPs in the country). Those e-waste sorting communities operate similarly to the practice of a code 105 industry which are sorting and dismantling wastes. For the most part, the sorting and disassembling activities of these communities is just a supplementary occupation during the agricultural off seasons. Most people involved are domestic workers or farmers. They simply just use basic tools such as hammers, drills, saw to separate e-waste parts. An e-waste sorting community therefore does not fall within the definition of a factory as well as standard of practice.

Code 105 industries are licensed to sort and dismantle unused materials. The Department of Industrial Works and Industrial Estates reported that there are 43 industries in 11 provinces but mostly clustered in the central region.

Code 106 industries refer to recycling industry in which the industry collects unused industrial products or used factory wastes, including hazardous materials, and produce raw materials or new products through industrial production methods under their type 106 factory license. There are 116 type 106 factories scattered in 21 provinces. Most of them are densely distributed in the central and western areas. There are few in parts of the North and the South.

Code 101 industries or central waste treatment refer to the companies that treat or eliminate waste in either liquid or solid forms. They are two types of code 101 industries 1) wastewater treatment plant for the reduction, removal, and treatment of pollution contained in wastewater and sludge or 2) waste incineration for complete combustion. There are 22 waste disposal facilities involved in the management of e-waste scattered in 10 provinces, mostly distributed in the central and eastern regions.

According to the field data collections and interviews, most of the discarded cell phones from all over the country were sent to sorting and dismantling facilities in the Maha Sarakham Province area. For computers and televisions, there are two paths for distribution: 1) waste is transported to the Suea Yai Uthit community in Bangkok where

the waste is sorted and dismantled in and around Bangkok or 2) waste is transported to Kalasin and Buriram provinces in the northeastern region. For air conditioners, most of the waste is sorted and dismantled in Bangkok, and not much waste is sent for sorting and dismantling in the Kalasin and Buriram provinces. From these practices, air conditioners are transported the shortest distance from the sorting and dismantling facilities and communities to the recycling industries (less than 130 kilometers). In contrast, cell phones are transported the longest distance (average 614.2 kilometers).

Conclusions

The status quo of e-waste management is not effective and is driven by the marketing mechanism with a focus on reducing costs. The workers in the informal sector are the main active group doing waste sorting and dismantling. For this reason, the practices are lack of waste management standard since they do not have knowledge and tools. This research aimed to understand the trade-offs among the economic value and environmental impacts of the current e-waste management system.

This study focused on four types of e-waste: cell phones, desktop computers, air conditioners, and televisions in 2019. According to our estimation model, there were approximately 89,499-257,567 tons that can be allocated as: 1) cell phones, 1,343-2,875 tons or 10.74-23.00 million units; 2) desktop computers, 16,250-58,178 tons or 1.25-4.47 million units; 3) air conditioners, 34,884-97,066 tons or 0.91-2.54 million units; and 4) televisions, 37,022-99,448 tons or 2.46-6.80 million units.

The value of e-waste parts can be divided into three main categories which are 1) waste or non-recyclable materials, e.g., glass with lead content (TV screens), plastic, and etc., accounted for 24% of the total e-waste generated, or 24,770-80,062 tons; 2) recyclable parts within the country, e.g., plastic, iron, copper and aluminum, accounted for 70%, or 68,859-231,032 tons; and 3) recyclable parts outside the country, e.g. circuit board and battery, accounted for 6%, or 5,998-19,965 tons. Table 7 showed the summary of these waste.

Table 7: Volumes and Parts of the Garbage and Valuable Parts Recycled Domestically and Exported Abroad.

Waste			**Domestic Recycling**			**Export for Recycling Abroad**	
Parts	Quantity (ton/year)		Parts	Quantity (ton/year)		Parts	Quantity
Plastic	381-708		Plastic	19,424-64,102		Battery	349-747
Screen/glass	16,488-65,004		Steel	40,322-126,329		Circuit board	5,649-19,218
Back light	2,162-5,652		Copper	5,216-16,483			
Other**	5,739-8,698		Aluminium	3,897-24,118			
Total	24,770-80,062		Total	68,859-231,032		Total	5,998-19,965
%	24			70			6

Because of illegal dumping of contaminated waste in landfill and no serious monitoring, the workers dismantling communities do not pay a landfill fee or a waste disposal fee. For this reason, they can gain profits from this practice. In fact, if they are responsible for these environmental externalities, dismantling TVs costs more than its profit. Existing waste management systems should be revised to internalize disposal costs in the related stakeholders e.g. producers or consumers (Kiddee et al., 2013). A new waste management system is needed to handle parts of the recycling process to create sustainable circular economy.

The government should communicate to consumers to discard e-waste instead of keeping at home. The government or private sectors can join at this step by offering inventive or promotion campaign e.g. old exchange for new models, discount, tax deduction etc.

Changes in the attitudes of governments, appropriate legislation dealing specifically with e-waste, control of electronic waste dumping, implementation of EPR, and transfer of technology for the sound recycling of e-waste are the keys for the effective management of e-waste (Nnorom and Osibanjob, 2008). “The Electrical and Electronic Equipment Waste Management Act” is in the drafting process for more than 10 years and should not be put on hold. Certain e-waste types might need to be charged a waste management fee because the collection and recycling have more embedded costs.

Collection guidelines and collection points will affect profitability and GHGs. To promote circular economy, therefore, a collection and sorting and dismantling center by region (North, Central, West, Northeast, East and South) needs to be established between dismantling facilities and recycling plants with transportation distance less than 400 km. Logistic management plays an important role for e-waste circular economy because e-waste could be considered as an opportunity for recycling or recovery of valuable metals (Awasthi et al., 2018). A full recycling plant in the country should be promoted for circuit boards and batteries for the complete extraction of precious minerals.

Ending informal recycling has been a policy objective for governments in many developing countries, including Thailand (Kahhat and Williams, 2012, Herat and Agamuthu, 2012). The informal sector should apply the best affordable technologies (BAT) and upgrade and qualify low- and medium-skilled laborers (Widmer et al., 2005). Practical feasibility of circular economy approaches and develop community commitment through active engagement of stakeholders should be promoted (Chakrabarty and Nandi, 2021, Fiksel et al., 2021).

Finally, considering public awareness and human risk attitude during the e-waste recycling activities would be beneficial for organizations in terms of reducing potential effects on society (Osibanjo and Nnorom, 2007) (Pariatamby and Victor, 2013).

Economic incentives play a pivotal role in developing countries usually have concerns regarding socio-economic and socio-political issues, while in developed nations higher levels of influential factors exist, including proximity, suitability and ease of access, and so forth (Shokouhyar and Shahrasbi, 2021). For Thailand, incentives might be needed to encourage people to discard e-waste at the collecting point and not together with the solid household waste (Kazancoglu et al., 2020). Future studies on experiences on consumers' e-waste disposal behavior and awareness could be helpful to devise inclusive e-waste management strategies to address the current challenges (Borthakur and Govind, 2017).

References

Awasthi, A. K., Cucchiella, F., D'Adamo, I., Lia, J., Rosa, P., Sergioterzi, Wei, G., & Zeng, X. (2018). Modelling the correlations of e-waste quantity with economic increase. *Science of The Total Environment, 613-614*, 46-53.

Borthakur, A., & Govind, M. (2017). Emerging trends in consumers' E-waste disposal behaviour and awareness: A worldwide overview with special focus on India. Resources, *Conservation and Recycling, 117*, 102-113.

Borthakur, A., & Govind, M. (2019). Computer and mobile phone waste in urban India: An analysis from the perspectives of public perception, consumption and disposal behaviour. *Journal of Environmental Planning and Management*, 62.

Buranasingha, N. (2016). Electronic waste. Bangkok: The Secretariat of the House of Representatives.

Chakrabarty, A., & Nandi, S. (2021). Electronic waste vulnerability: Circular economy as a strategic solution. Clean Technologies and Environmental Policy, 23, 429-443.

Department of Industrial Works. (2018). Predictions for the quantity of electric and electronic appliances and the flow cycle of the waste products: Project to increase efficiency of the separation and recycling plant for waste electrical and electronic products, fiscal year 2018.

Fetanat, A., Tayebi, M., & Shafipour, G. (2021). Management of waste electrical and electronic equipment based on circular economy strategies: Navigating a sustainability transition toward waste management sector. Clean Technologies and Environmental Policy, 23, 343-369.

Fiksel, J., Sanjay, P., & Raman, K. (2021). Steps toward a resilient circular economy in India. Clean Technologies and Environmental Policy, 23, 203-218.

Herat, S., & Agamuthu, P. (2012). E-waste: A problem or an opportunity? Review of issues, challenges and solutions in Asian countries. Waste Management & Research: The Journal for a Sustainable Circular Economy, 30, 1113-1129.

Kahhat, R., & Williams, E. (2012). Materials flow analysis of e-waste: Domestic flows and exports of used computers from the United States. Resources, Conservation and Recycling, 67, 67-74.

Kazancoglu, Y., Ozkan-Ozen, Y. D., Mangla, S. K., & Ram, M. (2020). Risk assessment for sustainability in e-waste recycling in circular economy. Clean Technologies and Environmental Policy.

Kiddee, P., Naidu, R., & Wong, H. (2013). Electronic waste management approaches: An overview. Waste Management, 33, 1237-1250.

Klangphol, P., Nimnoi, S., & Suwandamrongchai, R. (2019). Legal measures for the e-waste management in Thailand. Research Journal Rambhai Barni, 13, 111-118.

Kojima, M., Yoshida, A., & Sasaki, S. (2009). Difficulties in applying extended producer responsibility policies in developing countries: Case studies in e-waste recycling in China and Thailand. Journal of Material Cycles and Waste Management, 11, 263-269.

Manomaiwiboon, P. (2018). Forecast the amount of waste electrical and electronic products in Thailand and review technology for recycling abroad. Bangkok: Industrial Waste Management Division: Department of Industrial Works.

Mundada, M. N., Kumar, S., & Shekdar, A. V. (2004). E-waste: A new challenge for waste management in India. International Journal of Environmental Studies, 61, 265-279.

National Statistical Office. (2015). Statistics on number of households with air conditioning Retrieved from https://www.nso.go.th/sites/2014/Documents/info/Infographic59/8. Income/ 3.Income.pdf. [Accessed 15 May 2020].

National Statistical Office. (2017). Summary of important results of having a television viewing device in the household Retrieved from http://www.nso.go.th/sites/2014/DocLib13/onICT/Household Technology/2017/ SumDigital_TV-60.pdf. [Accessed 15 May 2020].

National Statistical Office. (2018). Information and Communication Technology (ICT) survey on the use of information and communication technology in the household Retrieved from http://www.nso.go.th/sites/2014/Pages/Survey/InformationTechnology/Household Technology.aspx. [Accessed 15 May 2020].

National Statistical Office. (2019). Information and Communication Technology (ICT) Survey of TV in household Retrieved from http://www.nso.go.th/sites/2014./Pages/Explore/InformationTechnology/Digital_TV-60.aspx. [Accessed May 15, 2020].

Nnorom, I. C., & Osibanjob, O. (2008). Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. Resources, Conservation and Recycling, 52, 843-858.

Office of Industrial Economics. (2015). Industry statistics: air conditioner sales volume between 2000-2015 Retrieved from https://indexes.oie.go.th/industrialStatistics1.aspx. [Accessed 15 May 2020].

Office of Industrial Economics. (2019). Industry statistics on the air conditioners sale in the country Retrieved from http://www.oie.go.th/view/1/IndustryStatistics/TH-TH#. [Accessed 15 May 2020].

Online Manager. (2019). Sales of smartphones in Thailand in 2018 shrink to 19.2 million units. Retrieved 20 August 2020 from Manager.

Osibanjo, O., & Nnorom, I. C. (2007). The challenge of electronic waste (e-waste) management in developing countries. The Journal for a Sustainable Circular Economy, 25.

Pariatamby, A., & Victor, D. (2013). Policy trends of e-waste management in Asia. Journal of Material Cycles and Waste Management, 15, 411-419.

Pollution Control Department. (2012a). Development of guidelines for assessing the quantity of e-waste [Online]. Bangkok: Ministry of Natural Resources and Environment. Retrieved from https://www.mofa.go.jp/mofaj/gaiko/oda/seisaku/kanmin/chusho_h25/pdfs/3a07-4.pdf. [Accessed May 2020].

Pollution Control Department. (2012b). The estimation of e-waste: a guideline development project prepared by the Electric and Electronics Institute. Bangkok: Ministry of Natural Resources and Environment.

Pollution Control Department. (2012c). Summary report for the management of the project development guidelines for the assessment of e-waste year 2012 Retrieved from https://www.mofa.go.jp/mofaj. /gaiko/oda/seisaku/kanmin/chusho_h25/pdfs/3a07-4.pdf. [Accessed 10 May 2020].

Pollution Control Department. (2019). Report of the situation of hazardous waste from the community in 2019. Ministry of Natural Resources and Environment.

Shokouhyar, S., & Shahrasbi, A. (2021). Revealing the reality behind consumers' participation in WEEE treatment schemes: A mixed method approach. Journal of Environmental Planning and Management.

Thailand Development Research Institute (TDRI). (2016). Electronic waste management in Thailand Retrieved from https://tdri.or.th/wp-content/uploads/2018/04/wb133.pdf. [Accessed 20 April 2019].

The Ellen MacArthur Foundation. (2023). What is a circular economy? Retrieved from https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview [Accessed 8 April 2024].

Wasanadamrongdee, S. (2015). The situation of electronic waste in Thailand: Academic discussion on "Electronic Waste: How to Manage It Safely?" Retrieved from https://thaipublica.org/2015/07/electronic-waste-1/. [Accessed 12 June 2015].

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Boni, H. (2005). Global perspectives on e-waste. Environmental Impact Assessment Review, 25, 436-458.